CHAPTER 8

TOPOGRAPHIC SURVEYING AND MAPPING

Topography refers to the characteristics of the land surface. These characteristics include **relief, natural features,** and **artificial** (or **man-made)** features. Relief is the conjuration of the earth's surface and includes such features as hills, valleys, plains, summits, depressions, and other natural features, such as trees, streams, and lakes. Man-made features are highways, bridges, dams, wharfs, buildings, and so forth.

A graphic representation of the topography of an area is called a **topographic map.** A topographic map is simply a drawing that shows the natural and artificial features of an area. A **topographic survey** is a survey conducted to obtain the data needed for the preparation of a topographic map. This data consists of the horizontal and vertical locations of the features to be shown on the map.

In this chapter and the following chapter, you will study methods and procedures used to perform topographic surveying and to prepare topographic maps.

TOPOGRAPHIC SURVEYING

The fieldwork in a topographic survey consists principally of (1) the establishment of a basic framework of horizontally and vertically located control points (called instrument points or stations) and (2) the determination of the horizontal and vertical locations of details in the vicinity of each instrument point. We will begin our discussions with topographic control.

TOPOGRAPHIC CONTROL

Topographic control consists of two parts: (1) horizontal control, which locates the horizontally fixed position of specified control points, and (2) vertical control, in which the elevations of specified bench marks are established. This control provides the framework from which topographic details, such as roads, buildings, rivers, and the elevation of ground points, are located.

Horizontal Control

Locating primary and secondary horizontal control points or stations may be accomplished by traversing, by triangulation (discussed in part 2 of this TRAMAN), or by the combined use of both methods. On an important, large-area survey, there may be both primary control, in which a number of widely separated primary control points are located with a high degree of precision; and secondary control, in which stations are located with less precision within the framework of the primary control points.

The routing of a primary traverse should be considered carefully. It should follow routes that will produce conveniently located stations. Such routes might run along roads, ridges, valleys, edges of wooded areas, public land lines, or near the perimeter of tracts of land. This latter route is of particular importance for small areas. When all the details in the area can be conveniently located from stations on the primary traverse, you do not need secondary traverses. However, the size or character of the terrain or both usually make secondary traverses necessary. Consider, for example, the situation shown in figure 8-1. This figure shows a tract bounded on three sides by highways and on the fourth side by a fence. For simplification, the figure shows only the items to be discussed. An actual complete plan would include a title, date, scale, north arrow, and so forth.

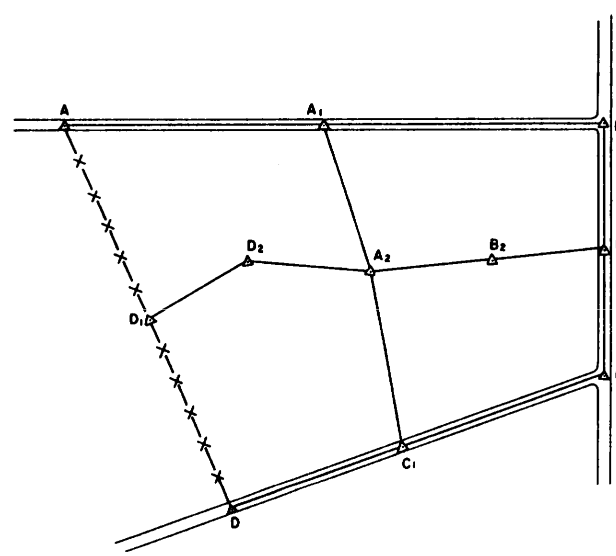


Figure 8-1.-Primary traverse and secondary traverse.

The primary traverse *ABCD* runs around the perimeter of the tract. Were this tract sufficiently small and level, then details within the whole tract could be located from only the primary control points; that is, from stations A, A_1, B, B_1, C, C_1, D, and D_1. In this case, however, the size (or perhaps the character) of the terrain made it necessary to establish additional control points within the perimeter of the tract, such as D_2, A_2, and B_2. These stations were established by running traverse lines (called crossties) across the area from one primary traverse station to another. It should be noted that, since each secondary traverse closes on a primary control point, errors cannot accumulate any farther than the distance between the primary stations.

Field notes for the survey sketched in figure 8-1 must contain (1) notes showing the horizontal locations of the stations and (2) level notes for determining the elevations of the stations.

Vertical Control

In topographic surveying, bench marks serve as starting and closing points for the leveling operations when you are locating details. Although for some surveys the datum may be assumed, it is preferable that all elevations be tied to bench marks which are referred to the sea-level datum. In many areas, particularly in the United States, series of permanent and precisely established bench marks are available. As a surveyor, you must make every feasible effort to tie in your surveys to these bench marks to ensure proper location and identification. Often, the established horizontal control marks are used as the bench marks because the level routes generally follow the traverse lines.

Vertical control is usually carried out by direct leveling; however, trigonometric leveling may be used for a limited area or in rough terrain. When you establish the primary vertical control to use in a topographic survey for an intermediate-scale map, four degrees of precision are used as follows:

1. **0.05 foot $\sqrt{\text{distance in miles}}$.** This order is used as the standard for surveys in flat regions when the contour interval is 1 foot or less. It is also used on surveys that require the determination of the gradient of streams or to establish the grades for proposed drainage and irrigation systems.

2. **0.1 foot $\sqrt{\text{distance in miles}}$.** This order is used in a survey when the contour interval of the map is 2 feet.

3. **0.3 foot $\sqrt{\text{distance in miles}}$.** This order is used for a contour interval of 5 feet.

4. **0.5 foot $\sqrt{\text{distance in miles}}$.** This order is used for a contour interval of 10 feet and may be done by stadia leveling, a method that is very advantageous in hilly terrain. Stadia will be discussed later in this chapter.

You use the third or fourth orders of precision for a large-scale map that generally has a contour interval of 1 or 2 feet. For an extensive survey of a large area, use the third order; for surveys of a smaller area, use the fourth order.

Once the topographic control has been established, your next major step in a topographic survey is to locate the details horizontally and vertically in the vicinity of each control point or station. These details consist of (1) all natural or artificial features that will appear on the map and (2) enough ground points and spot elevations to make the drawing of contour lines possible.

The methods and the instruments used in topographic surveys depend upon the purpose of the survey, the degree of precision needed, the nature of the terrain to be covered, the map scale, and the contour interval. For a high degree of accuracy, you should locate azimuths with a theodolite or transit. Measure horizontal distances with the chain or the electronic distance measurement (EDM) device. Determine elevations with a level.

The following sections discuss two methods that are commonly used to locate topographic details. A third method (topography by plane table) is discussed in the next chapter of this TRAMAN.

LOCATING DETAILS BY TRANSIT AND TAPE

In the EA3 TRAMAN you studied the procedures used to tie in and locate points, using a transit and tape. These same procedures are used for tying in and locating topographic details. Determine the vertical location (or elevation) of the detail points, using direct or trigonometric leveling procedures. Horizontally locate the details either by directions or distances or a combination of both. Use a method, or a combination of methods, that requires the least time in a particular situation. Directly measure the dimensions of structures, such as buildings, with tapes. When details are numerous, assign each one a number in the sketch and key the detail to a legend of some kind to avoid overcrowding. For directions, use azimuths instead of deflection angles to minimize confusion. Locate details as follows:

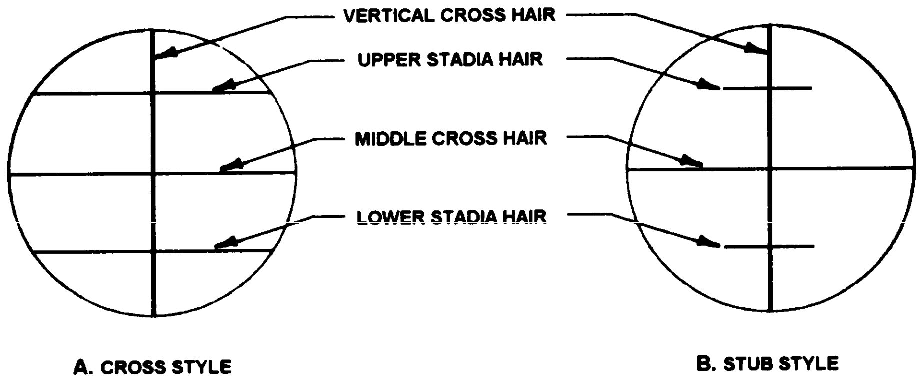


Figure 8-2.-Stadia hairs.

1. measure the angle and distance from transit stations
2. measure angles from two transit stations
3. measure distances from two known points
4. measure an angle from one station and distance from another station
5. measure swing offsets and range ties

As you can well imagine, detailing by transit and tape is a time-consuming process that requires chaining many distances and taking many level shots. This is necessary when a high degree of accuracy is required. However, for lower-precision (third and fourth order) surveys, a less time-consuming method is to locate the details by transit and stadia.

LOCATING DETAILS BY TRANSIT AND STADIA

As an EA, most of the topographic surveying that you will do is of a lower degree of accuracy that is well suited to the transit and stadia method. When you are using this method, horizontal distances and differences in elevation are indirectly determined by using subtended intervals and angles observed with a transit on a leveling rod or stadia board To explain the meaning of this, we will first discuss the principles of stadia and then look at field procedures that are used in stadia work.

Stadia Equipment Terms, and Principles

The following discussion will familiarize you with the equipment, terminology, and principles used in stadia surveying. Although this discussion of stadia surveying is included in this chapter on topography, you should be aware that stadia can be used in any situation in which it is desired to obtain horizontal distances and differences in elevation indirectly. The results, though, are of a lower order of precision than is obtainable by taping, EDM, or differential leveling. However, the results are adequate for many purposes, such as lower-order trigonometric leveling.

A thorough understanding of stadia is highly important to any surveyor. You should supplement the knowledge that you gain from the following discussion by reading other books, such as *Surveying Theory and Practice,* by Davis, Foote, Anderson, and Mikhail.

STADIA RODS.— Where sight distances do not exceed 200 feet, a conventional rod, such as a Philadelphia rod, is adequate for stadia work. For longer distances, however, you should use a stadia rod. Stadia rods usually have large geometric designs on them so that they may be read at distances of 1,000 to 1,500 feet or even farther. Some rods do not have any numerals on them. From the geometric pattern on the rod, you can observe intervals of a tenth of a foot and sometimes a hundredth of a foot.

Stadia rods generally are 10 to 15 feet long, 3 to 5 inches wide, and about 3/4 inch thick. They may be made in one piece or in sections for ease in carrying them. Some stadia rods are flexible and maybe rolled up when not in use. Flexible rods are merely graduated oilcloth ribbons, tacked to a board.

Some examples of stadia rods are shown in chapter 11 of the EA3 TRAMAN.

STADIA HAIRS.— The telescope of transits (as well as theodolites, plane-table alidades, and many levels) is equipped with two hairs, called **stadia hairs,** that are in addition to the regular vertical and horizontal cross hairs. Figure 8-2 shows two types of stadia hairs as viewed through a telescope. As shown in this figure, one stadia hair is located above and the other an equal distance below the horizontal (or middle) cross hair. On most equipment, the stadia hairs are not adjustable and remain equally spaced.

STADIA INTERVAL.— As you look at a stadia rod through a transit telescope, the stadia hairs seem to intercept an interval on the rod. The distance on the rod between the apparent positions of the two stadia hairs is the **stadia interval** or **stadia reading.**

Usually, you determine stadia intervals by sighting the lower stadia hair at a convenient foot mark and then observing the position of the upper stadia hair; for example, the lower hair might be sighted on the 2.00 foot mark and the upper hair might be in line with 6.37. By subtracting, we have the stadia reading (6.37 -2.00 = 4.37).

It may happen that the stadia reading is more than the length of the rod. By using the middle hair, you may observe a half-interval and multiply it by 2 to get the stadia reading.

STADIA CONSTANT.— Light rays that pass through the lens (objective) of a telescope come together at a point called the **principal focus** of the lens. Then these light rays continue in straight-line paths, as shown in figure 8-3.

The distance between the principal focus and the center of the lens is called the **focal** ***length(f)*** of the lens. For any particular lens, the focal length does not change. If you divide the focal length by the distance between the stadia hairs *(i),* you get a number known as the **stadia constant** *(k).* Sometimes the stadia constant is called the stadia factor or stadia interval factor.

A convenient value to use for the stadia constant is 100. Stadia hairs usually are spaced so that the interval between them will make the stadia constant equal to 100.

STADIA DISTANCE.— The distance from the principal focus to the stadia rod is called the **stadia distance.** As shown in figure 8-3, this distance *(d)* is

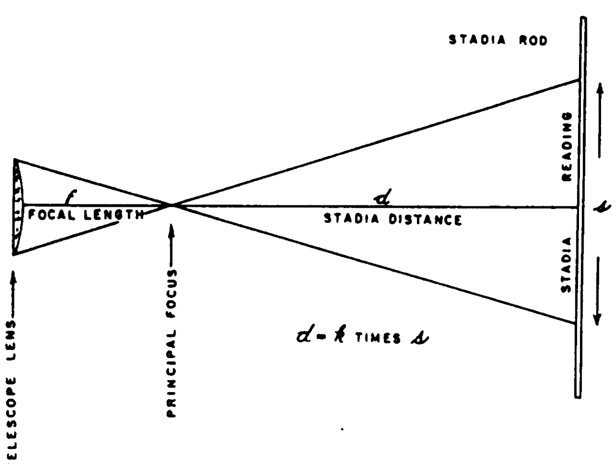


Figure 8-3.—Light rays converge at principal focus of a lens.

equal to the stadia constant ***(k)*** times the stadia reading *(s).*

INSTRUMENT CONSTANT.— The distance from the center of the instrument to the principal focus is the **instrument constant.** Usually, this constant is determined by the manufacturer of the instrument. You should find it stated on the inside of the instrument box.

Externally focusing telescopes are manufactured so that the instrument constant may be considered equal to 1. For internally focusing telescopes, though, the objective in the telescope is so near the center of the instrument that the instrument constant may be considered as zero. This, as you will learn in the following discussion of stadia reduction formulas, is a distinct advantage of internally focusing telescopes. Most modem instruments are equipped with internally focusing telescopes.

STADIA REDUCTION FORMULAS.— In stadia work we are concerned with finding two values as follows: (1) the horizontal distance from the center of the instrument to the stadia rod and (2) the vertical distance, or difference in elevation, between the center of the instrument and middle-hair reading on the rod. To obtain these values, you must use **stadia reduction formulas.**

Stadia Formula for Horizontal Sights.— For a horizontal sight, the distance that we need to determine is the horizontal distance between the center of the instrument and the stadia rod. This distance is found by adding the stadia distance to the instrument constant as follows:

Write ks for the stadia distance and $(f + c)$ for the instrument constant. Then the formula for computing horizontal distances when the sights are horizontal becomes the following:

$$h = ks + (f + c).$$

Where:

h = horizontal distance from the center of the instrument to a vertical stadia rod

k = stadia constant, usually 100

s = stadia interval

$f + c$ = instrument constant (zero for internally focusing telescopes; approximately 1 foot for externally focusing telescopes)

f = focal lengths of the lens

c = distance from the center of the instrument to the center of the lens

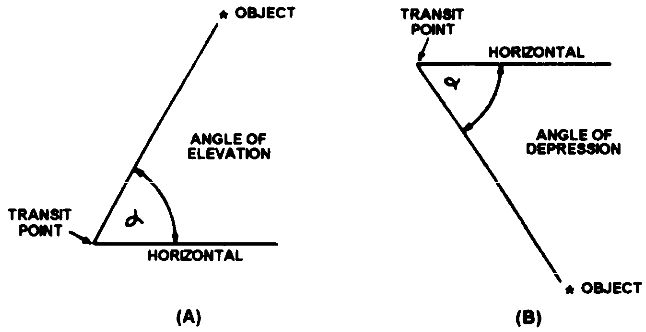


Figure 8-4.-(A) Angle of elevation and (B) angle of depression.

The instrument constant is the same for all readings. Suppose that you are using an externally focusing instrument with an instrument constant of 1.0. If the stadia interval is 1 foot, then the horizontal distance is as follows:

$$h = (100)(1) + 1 = 101 \text{ feet.}$$

If the stadia interval is 2 feet, the horizontal distance is as follows:

$$h = (100)(2) + 1 = 201 \text{ feet.}$$

Now suppose that you are using an internally focusing instrument. In this case, the instrument constant is zero and can be disregarded. This is the advantage of an internally focusing telescope. So, if the stadia interval is 1 foot, the horizontal distance is simply the stadia distance which is 100 feet. For a stadia reading of 2 feet, the horizontal distance is 200 feet.

Horizontal distance usually is stated to the nearest foot. Occasionally on short distances (under 300 feet), it maybe specified that tenths of a foot be used.

Stadia Formulas for Inclined Sights.— -Most often the sights needed in stadia work are not horizontal. It may be necessary to incline the telescope upward or downward at a vertical angle. This vertical angle (α) may be either an angle of elevation or an angle of depression, as shown in figure 8-4. If the line of sight is elevated above the horizontal, you speak of it as an **angle of elevation.** If the line of sight is depressed below the horizontal, the vertical angle is an **angle of depression.**

In either case, you find the horizontal and vertical distances by using the following formulas:

$$h = ks\cos^2\alpha + (f + c)\cos\alpha$$

$$v = 1/2ks\sin 2\alpha + (f + c)\sin\alpha$$

These two expressions are called the stadia formulas for inclined sights in which

h = horizontal distance

v = vertical distance

h = stadia distance

a = vertical angle

$f + c$ = instrument constant

Refer to figure 8-5 for clarification of the terms in the stadia formulas for inclined sights.

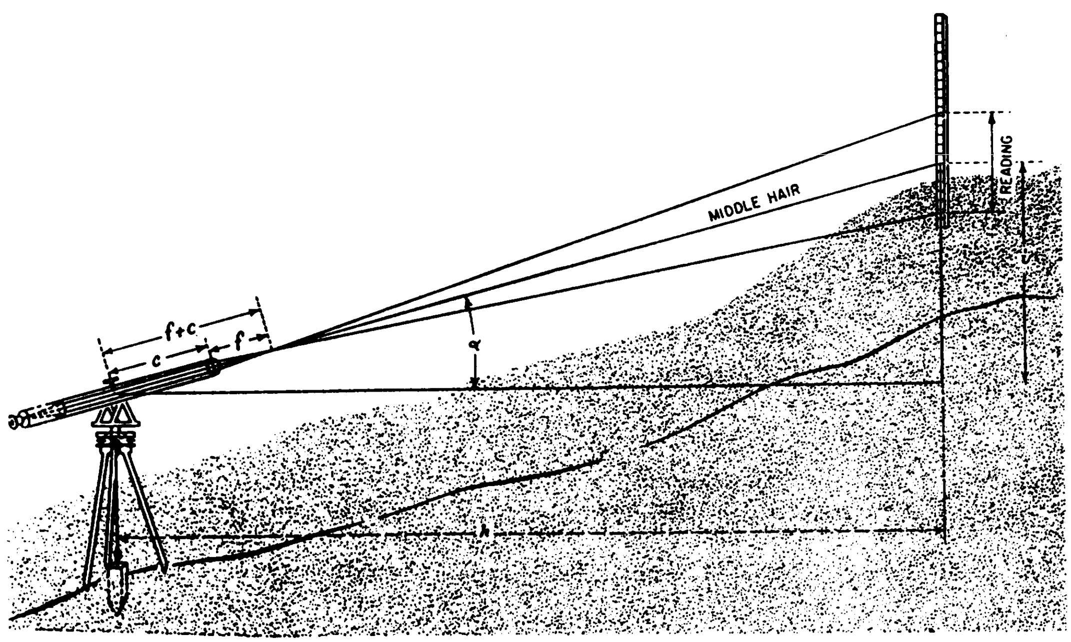


Figure 8-5.-Stadia Interval—inclined sight.

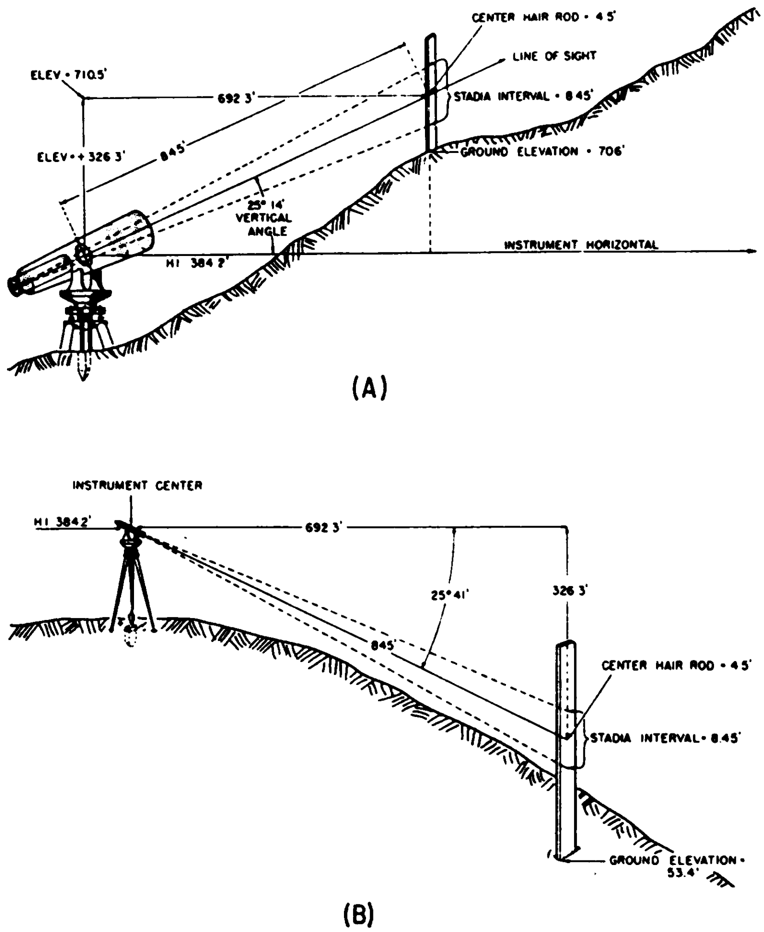


Figure 8-6.—Ground elevations: (A) Telescope raised and (B) telescope depressed.

DISTANCE AND ELEVATION FOR INCLINED SIGHTS.— The following example will describe the use of the stadia reduction formulas for inclined sights. Assume you have a stadia interval of 8.45 and an angle of elevation of 25°14', as shown in figure 8-6, view A. Let the instrument constant be 1.0.

Substituting the known values in the stadia formula for the horizontal distance, you have

$$h = ks\cos^2\alpha + (f + c)\cos\alpha$$

$$h = 100\ (8.45)\ (0.90458)^2 + (1)\ (0.90458) = 692.34$$

The horizontal distance is 692 feet.

Substituting the known values in the formula for the vertical distance, you have

$$v = 1/2\, ks \sin 2\alpha + (f + c)\sin\alpha$$

$$v = 50\ (8.45)\ (0.77125) + (1)\ (0.42631)$$

$$v = 326.28.$$

The vertical distance to the middle-hair reading on the rod is 326.28 feet.

To find the elevation of the ground at the base of the rod, subtract the center-hair rod reading from this vertical distance and add the height of instrument (HI). (See fig. 8-6, view A). If the HI is 384.20 feet and the center-hair rod reading is 4.50 feet, then the ground elevation is

$$326.28 - 4.5 + 384.20 = 705.98 \text{ feet}$$

If the angle of inclination were depressed, then you would have to add the center-hair rod reading to the vertical distance and subtract this sum from the HI. As you see from figure 8-6, view B, the ground elevation would be

$$384.2 - (326.28 + 4.5) = 53.42 \text{ feet.}$$

STADIA TABLES.— You may save time in finding the horizontal distance and the vertical distance (difference in elevation between two points) by using the stadia reduction tables in appendix II. Here the values of 100 $\cos^2\alpha$ and 1/2(100) sin 2α are already computed at 2-minute intervals for angles up to 30°. You need to multiply the values in the table by the stadia reading, then add the value of the instrument constant given at the bottom of the page.

To find the values from the stadia table, for the example that we have been discussing, read under 25° and opposite **14′.** Under Hor. Dist. you find that

$$100 \text{ COS}^2 25°14' = 81.83.$$

Under Diff. Elev. you see that

$$1/2\ (100) \sin 2\ (25°14') = 38.56.$$

The values of the term containing the instrument constant are given at the bottom of the page.

For

$$(f + c) = C = 1.00.$$

You find

$$(f + c) \cos \alpha = 0.90.$$

Therefore

$$(f + c) \sin \alpha = 0.43.$$

Using these values in the formulas, you have

$$h = 8.45\ (81.83) + 0.90$$

$$h = 692.4 \text{ or } 692 \text{ feet.}$$

and

$$v = 8.45\ (38.56) + 0.43$$

$$v = 326.23 \text{ or } 326 \text{ feet.}$$

APPROXIMATE FORMS OF STADIA FORMULAS.— Because of the errors common in stadia surveying, it has been found that approximate stadia formulas are precise enough for most stadia work If you will refer again to figures 8-5 and 8-6, you will notice that it is customary to hold the stadia rod plumb rather than inclined at right angles to the line of sight. Failure to hold the rod plumb introduces an error causing the observed readings to be longer than the true readings. Another error inherent in stadia surveying is caused by the unequal refraction of light rays in the layers of air close to the earth's surface. The refraction error is smallest when the day is cloudy or during the early morning or late afternoon hours on a sunny day. Unequal refraction, also, causes the observed readings to be longer than the true readings.

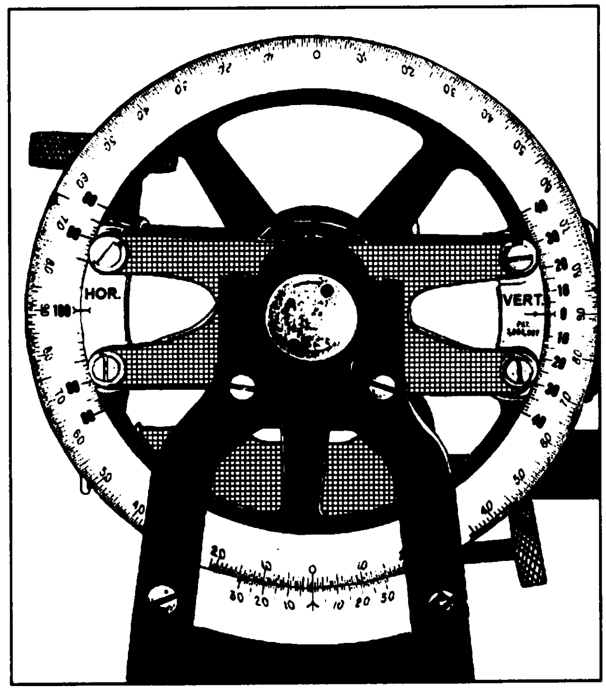


Figure 8-7.-Stadia arc (multiplier type).

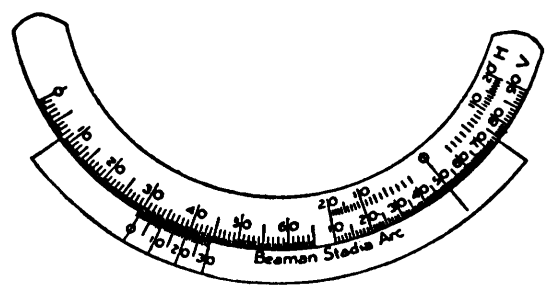


Figure 8-8.-Stadia arc (horizontal scale subtraction type).

To compensate for these errors, topographers often regard the instrument constant as zero in stadia surveying of ordinary precision, even if the instrument has an externally focusing telescope. In this way, the last terms in the stadia formulas for inclined sights vanish; that is, become zero. Then the **approximate expressions for horizontal and vertical distance** are

$$h = ks \cos^2\alpha$$

$$v = 1/2ks \sin 2\alpha.$$

BEAMAN STADIA ARC.— The Beaman stadia arc is a specially graduated arc on the vertical scale of the transit (fig. 8-7) or on the plane-table alidade (fig. 8-8). The Beaman arc on the transit is also known as the **stadia circle.** These arcs are used to determine distances and differences in elevation by stadia without using vertical angles and without using tables or diagrams. A stadia arc has no vernier, but readings are indicated by index marks.

The stadia arc shown in figure 8-7 is the **multiplier** stadia arc (the vertical index is at zero); that is, the observed stadia interval is multiplied by the **Hor** stadia arc reading to get the horizontal distance; or the stadia interval is multiplied by the Vert stadia arc reading to obtain the vertical distance from the center of the instrument to the point sighted on the rod This vertical distance, combined with the HI and the rod reading, will give the difference in elevation between the instrument station and the point where the rod is held

The stadia arc, as shown is figure 8-8, is called the horizontal scale **subtraction** stadia arc (the vertical index is at 50). The use of the Beaman stadia arc to obtain a horizontal distance and difference in elevation is explained in the following sections.

Horizontal Distance (Subtraction Scale).— The **H** scale gives you a percentage that you can apply to an inclined stadia shot with the alidade to get the corresponding horizontal distance from the slope distance. Suppose that with the telescope inclined (that is, at a vertical angle other than 0°), you read an interval of 2.45 feet on the stadia rod. The slope distance, then

$$2.45 \times 100 = 245 \text{ feet.}$$

What is the corresponding horizontal distance? You read the graduation indicated by the Beaman arc indicator on the H scale, and find that the reading is 5. This means that the horizontal distance is 5 percent less than the slope distance, or

$$245 \text{ feet} - (0.05 \times 245 \text{ feet}), \text{ or}$$

$$245 - 12.25 = 232.8 \text{ feet.}$$

Difference in Elevation (Vertical Index at 50).— The **V** scale on the Beaman arc is used to determine the difference in elevation between the elevation of the line of sight through the telescope (that is, the HI) and the elevation of the point you sighted on the level rod Note that when the telescope is horizontal, the **V** scale on the Beaman arc reads 50. This arrangement makes the use of minus values unnecessary when you are sighting with the telescope at a negative vertical angle.

To read the **V** scale, you take the difference between 50 and whatever you read on the scale and apply this difference as follows to determine the difference in elevation.

Suppose that when you made the shot previously described (where you read 5 on the **H** scale), the reading on the **V** scale was 71. In practice, it is the custom to shoot the rod at a point that will give you an even reading on the **V** scale.

Because the reading was 71, the value you will use is

$$71 - 50, \text{ or } 21\%.$$

This means that the difference in elevation between the HI and the point you sighted on the rod is 21 percent of the slope distance. The slope distance, in this case, was 245.0 feet; therefore, the difference in elevation is

$$245.0 \times 0.21 = 51.45 \text{ feet.}$$

Now that you know how to read stadia and compute horizontal and vertical distances using stadia, we will now discuss typical field procedures.

Field Procedures

Figure 8-9 shows two situations that are encountered in transit-stadia work First, let us discuss the common situation in which you desire to determine the difference in elevation between an instrument station of known elevation and a ground point of unknown elevation. This situation is shown in figure 8-9, view A. In this view, the elevation of the instrument station P is known and it is desired to determine the difference in elevation between P and the rod station P_1. The horizontal center-line height of the instrument (h.i.) above point P *is* equal to PA. As you can see, this h.i. is different than the HI that you are accustomed to working with indirect leveling. The rod reading is P_1B.

From your studies, you know that the difference in elevation *(DE)* between P and P_1 can be expressed as follows:

$$DE = PA + BC - P_1B$$

$$\text{or, } DE = h.i. + BC - P_1B.$$

Therefore, the ground elevation at P_1 can be expressed as follows:

$$\text{Elev. } P_1 = \text{Elev. } P + (h.i. + BC - P_1B).$$

Now let us sight on the rod such that $P_1B = PA$ = h.i. In this case, the situation occurs in which a similar triangle (PC_1P_1) is formed at the instrument station P. From observation of these similar triangles, you can see that the DE= $P_1C_1 = BC$. Therefore, the ground elevation at P_1 *can be* simply expressed as follows:

$$\text{Elev. } P_1 = \text{Elev. } P + BC.$$

This is an important concept to understand when shooting stadia from a station of known elevation As

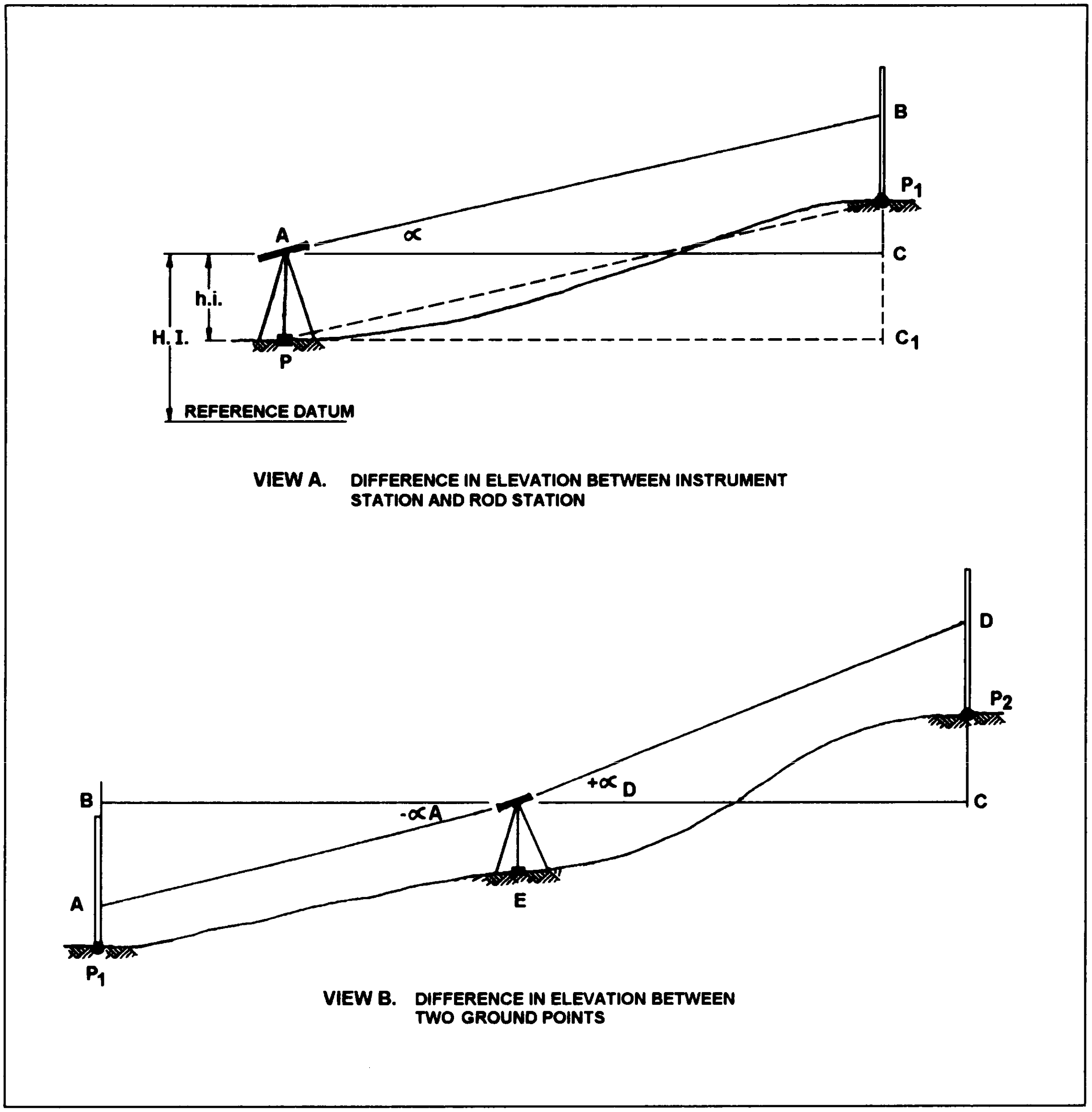


Figure 8-9.-Difference in elevation.

you can see, when the center cross hair is sighted on a rod graduation that is equal to the h.i. before reading the vertical angle, then calculating the difference in elevation is greatly simplified. Obviously, though, if the line of sight is obstructed and you cannot sight on a rod graduation that is equal to the hi., then you must sight on some other graduation.

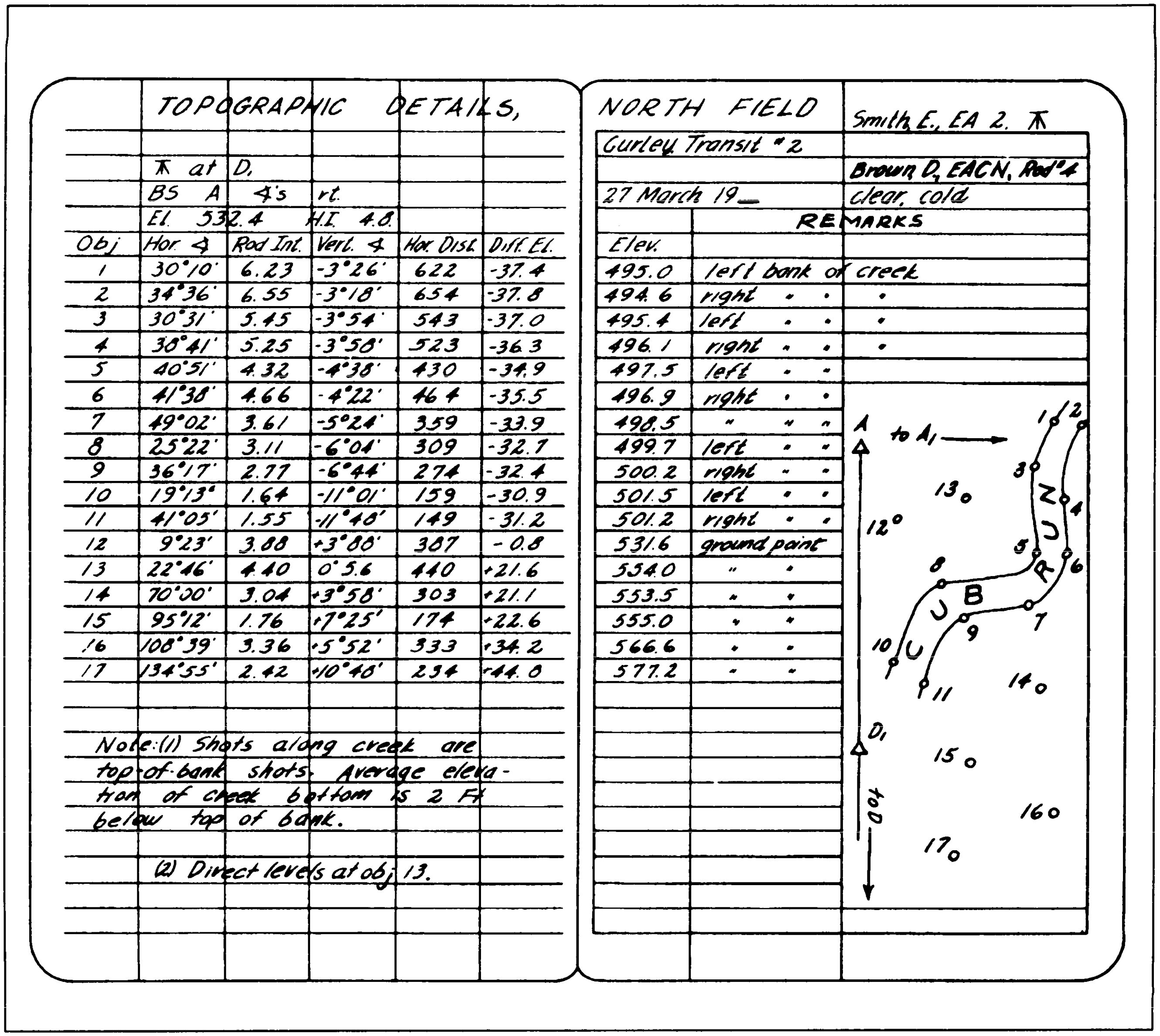
Another, although less frequent, occurrence in topographic work using stadia is shown in figure 8-9, view B. In this situation it is desired to determine the difference in elevation between two points on the ground (P_1 and P_2) from an instrument station (E) that is located between the two points.

For this discussion, let us assume that a backsight is taken on a rod held at P_1 and then a foresight is taken to P_2. Now the difference in elevation *(DE)* between the two points can be written as follows:

$$DE = P_1A + AB + CD - P_2D.$$

In reverse, if a backsight was taken to P_2 with a foresight to P_1, then the expression for *DE* can be written as follows:

$$DE = CD - P_2D - AB - P_1A.$$



TOPOGRAPHIC DETAILS, NORTH FIELD

Gurley Transit #2 | Smith E., EA 2. ⊼ | Brown D., EACN, Rod #4

27 March 19__ | clear, cold

⊼ at D_1

BS A ∡'s rt.

El. 532.4 H.I. 4.8

Obj	Hor. ∡	Rod Int.	Vert. ∡	Hor. Dist.	Diff. El.	Elev.	REMARKS
1	30°10'	6.23	-3°26'	622	-37.4	495.0	left bank of creek
2	34°36'	6.55	-3°18'	654	-37.8	494.6	right " " "
3	30°31'	5.45	-3°54'	543	-37.0	495.4	left " " "
4	38°41'	5.25	-3°58'	523	-36.3	496.1	right " " "
5	40°51'	4.32	-4°38'	430	-34.9	497.5	left " "
6	41°38'	4.66	-4°22'	464	-35.5	496.9	right " "
7	49°02'	3.61	-5°24'	359	-33.9	498.5	" " "
8	25°22'	3.11	-6°04'	309	-32.7	499.7	left " "
9	36°17'	2.77	-6°44'	274	-32.4	500.2	right " "
10	19°13'	1.64	-11°01'	159	-30.9	501.5	left " "
11	41°05'	1.55	-11°48'	149	-31.2	501.2	right " "
12	9°23'	3.88	+3°88'	387	-0.8	531.6	ground point
13	22°46'	4.40	0°5.6	440	+21.6	554.0	" "
14	70°00'	3.04	+3°58'	303	+21.1	553.5	" "
15	95°12'	1.76	+7°25'	174	+22.6	555.0	" "
16	108°39'	3.36	+5°52'	333	+34.2	566.6	" "
17	134°55'	2.42	+10°48'	234	+44.0	577.2	" "

Note: (1) Shots along creek are top-of-bank shots. Average elevation of creek bottom is 2 Ft below top of bank.

(2) Direct levels at obj. 13.

Figure 8-10.-Notes for locating topographical details by transit and stadia.

Now let us see how all that you have learned about transit-stadia topography is used in the field Figure 8-10 shows field notes for locating topographic details by transit and stadia. The details shown by numbers in the sketch on the Remarks side are listed on the data side by numbers in the column headed Obj. At the top of the page on the data side, you see that control point D_1 was used as the instrument station. Immediately below this, you see that from instrument-station D_1, the transit was backsighted to point A and that all horizontal angles were measured to the right from the backsight on A.

In the third line from the top on the data side, you see that the known elevation of D_1 *is* 532.4 feet and that the vertical distance (hi.) from the point or marker at D_1 to the center of the instrument above D_1 is 4.8 feet. This vertical distance was carefully determined by measurement with a tape or rod held next to the instrument.

Now let us see how each of the objective points was detailed. We will begin with point 1. Remember that in this example, D_1 *is the* instrument station from which all observations are made.

To determine the direction of point 1, train the transit telescope on A and match the zeros. Next turn the telescope right to train on point 1 and read the horizontal angle (30°10′).

Minutes	0° Hor. dist.	0° Diff. elev.	1° Hor. dist.	1° Diff. elev.	2° Hor. dist.	2° Diff. elev.	3° Hor. dist.	3° Diff. elev.
0	100.00	0.00	99.97	1.74	99.88	3.49	99.73	5.23
2	100.00	0.06	99.97	1.80	99.87	3.55	99.72	5.28
4	100.00	0.12	99.97	1.86	99.87	3.60	99.71	5.34
6	100.00	0.17	99.96	1.92	99.87	3.66	99.71	5.40
8	100.00	0.23	99.96	1.98	99.86	3.72	99.70	5.46
10	100.00	0.29	99.96	2.04	99.86	3.78	99.69	5.52
12	100.00	0.35	99.96	2.09	99.85	3.84	99.69	5.57
14	100.00	0.41	99.95	2.15	99.85	3.90	99.68	5.63
16	100.00	0.47	99.95	2.21	99.84	3.95	99.68	5.69
18	100.00	0.52	99.95	2.27	99.84	4.01	99.67	5.75
20	100.00	0.58	99.95	2.33	99.83	4.07	99.66	5.80
22	100.00	0.64	99.94	2.38	99.83	4.13	99.66	5.86
24	100.00	0.70	99.94	2.44	99.82	4.18	99.65	5.92
26	99.99	0.76	99.94	2.50	99.82	4.24	99.64	5.98
28	99.99	0.81	99.93	2.56	99.81	4.30	99.63	6.04
30	99.99	0.87	99.93	2.62	99.81	4.36	99.63	6.09
32	99.99	0.93	99.93	2.67	99.80	4.42	99.62	6.15
34	99.99	0.99	99.93	2.73	99.80	4.48	99.62	6.21
36	99.99	1.05	99.92	2.79	99.79	4.53	99.61	6.27
38	99.99	1.11	99.92	2.85	99.79	4.59	99.60	6.33
40	99.99	1.16	99.92	2.91	99.78	4.65	99.59	6.38
42	99.99	1.22	99.91	2.97	99.78	4.71	99.59	6.44
44	99.98	1.28	99.91	3.02	99.77	4.76	99.58	6.50
46	99.98	1.34	99.90	3.08	99.77	4.82	99.57	6.56
48	99.98	1.40	99.90	3.14	99.76	4.88	99.56	6.61
50	99.98	1.45	99.90	3.20	99.76	4.94	99.56	6.67
52	99.98	1.51	99.89	3.26	99.75	4.99	99.55	6.73
54	99.98	1.57	99.89	3.31	99.74	5.05	99.54	6.78
56	99.97	1.63	99.89	3.37	99.74	5.11	99.53	6.84
58	99.97	1.69	99.88	3.43	99.73	5.17	99.52	6.90
60	99.97	1.74	99.88	3.49	99.73	5.23	99.51	6.96
C=0.75	0.75	0.01	0.75	0.02	0.75	0.03	0.75	0.05
C=1.00	1.00	0.01	1.00	0.03	1.00	0.04	1.00	0.06
C=1.25	1.25	0.02	1.25	0.03	1.25	0.05	1.25	0.08

Figure 8-11.-Horizontal distances and elevations from stadia readings.

For the horizontal distance and elevation of point 1, set a rod on the point, and train the lower stadia hair of the transit telescope on a whole-foot mark on the rod so that the center hair is near the 4.8 graduation. (This is a common practice in stadia work that makes reading the stadia interval easier.) Then read and record the stadia interval (in this case 6.23 feet). Next, rotate the telescope about the horizontal axis until the center hair is on the 4.8 rod graduation. Lock the vertical motion and read and record the vertical angle (-3026'). Be sure to record each vertical angle correctly as plus or minus. While you are reading and recording the vertical angle, the rodman can be moving to the next point. This will help speed up the survey.

From the stadia interval and the vertical angle reading, the horizontal distance (entered in the fifth column of fig. 8-10) and the difference in elevation (in the sixth column) are determined from a stadia reduction table. Figure 8-11 shows the page from a stadia reduction table that applies to the data for point 1 in figure 8-10. For this point, the vertical angle is **–3°26′,** and the stadia interval is 6.23 feet. In the table under 3° and opposite **26′,** note that the multiplier for horizontal distance is 99.64, while the one for difference in elevation is 5.98. If the final distance is ignored, the horizontal distance is

$$6.23 \times 99.64 = 620.75 \text{ (or 621 feet).}$$

The difference is elevation is

$$6.23 \times 5.98 = 37.3 \text{ feet.}$$

To these figures, add the corrections for focal distance given at the bottom of the page. For an instrument with a focal distance of 1 foot, add 1 foot to the horizontal difference (making a total horizontal distance of 622 feet) and 0.06 foot to the difference in elevation This makes the difference in elevation round off to 37.4 feet; and since the vertical angle has a negative (-) sign, the difference in elevation is recorded as –37.4 feet.

In the first column on the Remarks side of figure 8-10, enter the elevation of each point, computed as follows. For point 1, the elevation equals the elevation of instrument station D_1(532.4 feet) minus the difference in elevation (37.4 feet), or 495.0 feet. Subtract the difference in elevation, in this case, because the vertical angle you read for point 1 was negative. For a positive vertical angle (as in the cases of points 12 and 13 through 17 of your notes), add the difference in elevation

The remainder of the points in this example were detailed in a similar reamer except for point 13. When a detail point is at the same, or nearly the same, elevation as the instrument station, the elevation can be determined more readily by direct leveling. 'That was the case for point 13. As seen in the vertical-angle column of the notes, the vertical angle was 0° at a rod reading of 5.6 feet. Therefore the elevation of point 13 is equal to the elevation of the instrument station (532.4 feet) plus the h.i. (4.8 feet) minus the rod reading (5.6 feet), or 531.6 feet.

In the above example, as you recall, the transit was initially backsighted to point *A* and the zeros were matched This was because the azimuth of D_1A was not known. However, if you knew the azimuth of D_1A, you could indicate your directions in azimuths instead of in angles right from D_1A. Suppose, for example, that the azimuth of D_1A was **26°10′.** Train the telescope on *A* and set the horizontal limb to read **26°10′.** Then when you train on any detail point, read the azimuth of the line from D_1 to the detail point.

TOPOGRAPHIC MAPPING

Now you know how to perform and record a topographic survey, using the transit-tape or tranSit-stadia methods. Next, we will see how the draftsman (who also might be you) prepares a topographic map. To enhance the explanation of topographic mapping, we will also discuss some additional field methods the surveyor uses.

REPRESENTATION OF RELIEF

One of the purposes of a topographic map is to depict relief. In fact, this is the main feature that makes a topographic map different from other types of maps. Before you go any further, refresh your memory on the subject of topographic relief. *Relief* is the term for variance in the vertical configuration of the earth's surface. You have seen how relief can be shown in a plotted profile or cross section. These, however, are views on a vertical plane, but a topographic map is a view on a horizontal plane. On a map of this type, relief may be indicated by the following methods.

A relief model is a three-dimensional relief presentation-a molded or sculptured model, developed in suitable horizontal and vertical scales, of the hills and valleys in the area.

Shading is a pictorial method of showing relief by the use of light and dark areas to suggest the shadows that would be created by parallel rays of light shining across the area at a given angle.

Hachures area pictorial method similar to shading except that the light-and-dark pattern is created by short hachure lines, drawn parallel to the steepest slopes. Relative steepness or flatness is suggested by varying the lengths and weights of the lines.

Contour lines are lines of equal elevation; that is, each contour line on a map is drawn through a succession of points that are all at the same elevation. A contour is the real-life equivalent; that is, a line of equal elevation on the earth's surface.

All of these methods of indicating relief are illustrated in figure 8-12. The contour-line method is the one most commonly used on topographic maps.

CONTOUR LINES

Contour lines indicate a vertical distance above, or below, a datum plane. Contours begin at sea level, normally the zero contour, and each contour line represents an elevation above (or below) sea level. The

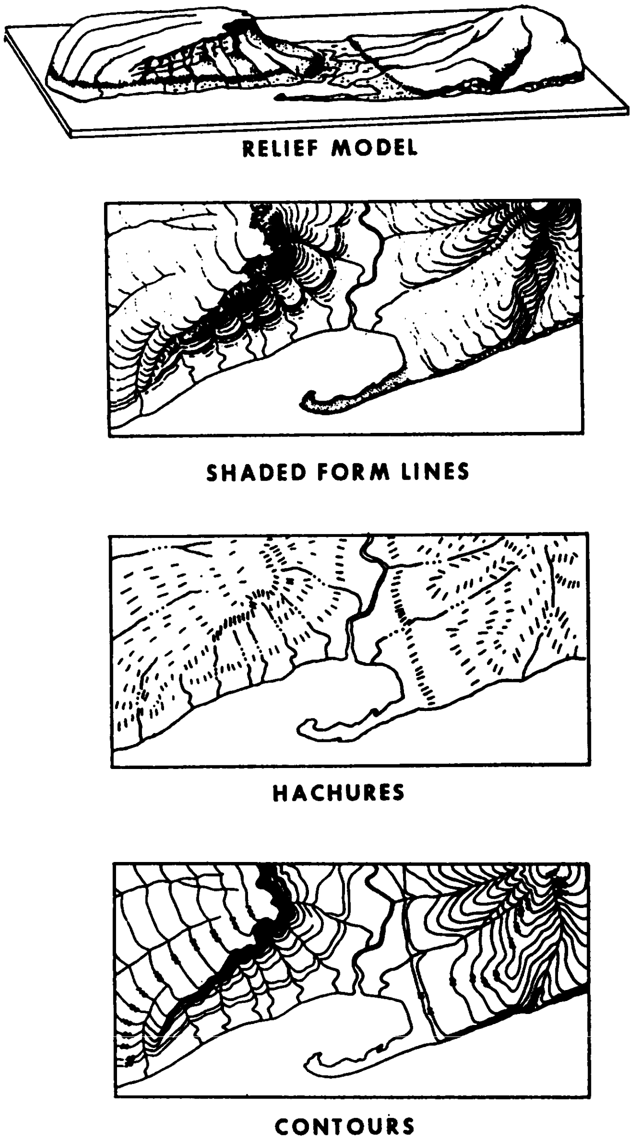


Figure 8-12.-Methods of indicating relief.

vertical distance between adjacent contour lines is known as the contour interval. Starting at zero elevation the topographer draws every fifth contour line with a heavier line. These are known as index contours. At some place along each index contour, the line is broken and its elevation is given. The contour lines falling between index contours are called intermediate contours. They are drawn with a finer line than the index contours and, usually, do not have their elevations given. Examples of index contours and intermediate contours are shown in figure 8-13.

GROUND POINT SYSTEMS

The essential data for showing relief by contour lines consists of the elevation of a sufficient number of ground points in the area. Methods of determining the horizontal and vertical locations of these ground points are called ground point systems. The systems most frequently used are (1) tracing contours, (2) grids, (3) control points, and (4) cross profiles. In practice, combinations of these methods may be used in one survey.

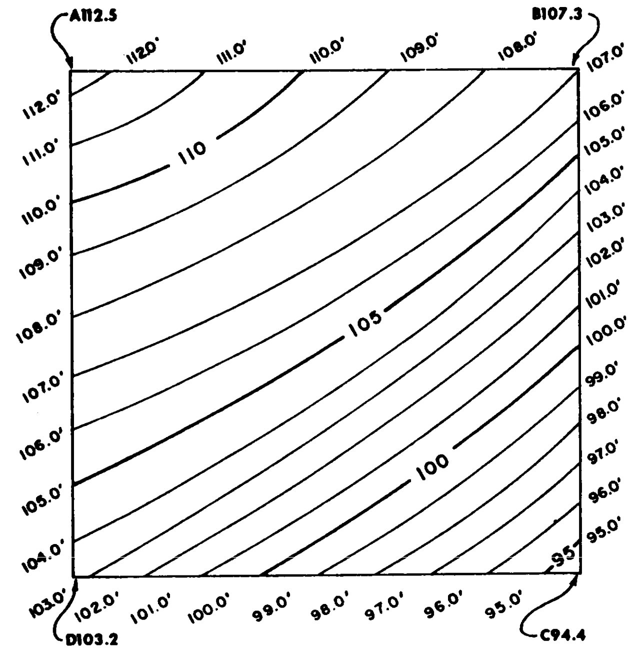


Figure 8-13.—Traverse with contour lines.

Tracing Contours

In the tracing contours system, the ground points located are points on the actual contours. Points on a given contour are plotted on the map, and the contour line is drawn through the plotted points. The method may be illustrated by the following simple example.

Refer again to the traverse shown in figure 8-13. In this figure, assume that the traverse runs around the perimeter of a small field. The elevations at comers *A, B, C,* and *D* are as shown. Obviously the ground slopes downward from AB toward *DC* and from *AD* toward *BC.*

You want to locate contours at a contour interval of 1 fret; that is, you want to plot the 112-foot contour line, the 110-contour line, the 110-foot contour line, and so forth. In this example, we will assume that the required order of precision is low, such as you may encounter in a reconnaissance survey, and because of this you are using a hand level.

You stand at station *A* with a hand level. The elevation of this station is 112.5 feet. Assume that the vertical distance from your eye level to the ground is 5.7 feet. Then with the hand level at your eye and with you standing on station *A,* the HI is

$$112.5 + 5.7 = 118.2 \text{ feet.}$$

If a level rod is set up anywhere on the 112.0-foot contour, the reading you would get from station *A* would be

$$118.2 - 112.0 = 6.2 \text{ feet.}$$

Therefore, to determine the point where the 112.0 foot contour crosses *AB,* you only need to have the rodman back out from point *A* along *AB* until he comes to the point where you read 6.2 feet on the rod. You can determine the point where the 112.0-foot contour crosses *AD* in the same reamer as *AB.* You can measure the distance from *A* to each point and then record the distance from *A* to the 112.0-foot contour on *AB* and *AD.*

When all of the contours have been located on *AB* and *AD,* you can shift to station C and carry out the same procedure to locate the contours along *BC* and *CD.* You have now located all the points where contours at a l-foot interval intersect the traverse lines. If the slope of the ground is uniform (as it is presumed to be in fig. 8-13), you can plot the contour lines by simply drawing lines between points of equal elevation, as shown in that figure. If there were irregularities in the slope, you would send the rodman out along one or more lines laid across the irregular ground, locating the contours on these lines as you located them on the traverse lines.

Grid Coordinate System

In the grid coordinate system, the area is laid out in squares of convenient size, and the elevation of each comer point is determined. While this method lends itself to use on relatively level ground, ridge or valley lines must be located by spot elevations taken along the lines. The locations of the desired contours are then determined on the ridge and valley lines and on the sides of the squares by interpolation. This gives a series of points through which the contour lines may be drawn

Figure 8-14 illustrates this method. Assume that the squares here measure 200.0 feet on each side. Points *a, b,* and *c* are points on a ridge line, also 200.0 feet apart. You need to locate and draw the 260.0-foot contour line. By inspection, you can see that the 260.0-foot contour must cross *AD* since the elevation of *A* is 255.2 feet and the elevation of *D* is 263.3 feet. However, at what point does the 260.0-foot contour cross *AD?* This can be determined by using a proportional equation as follows.

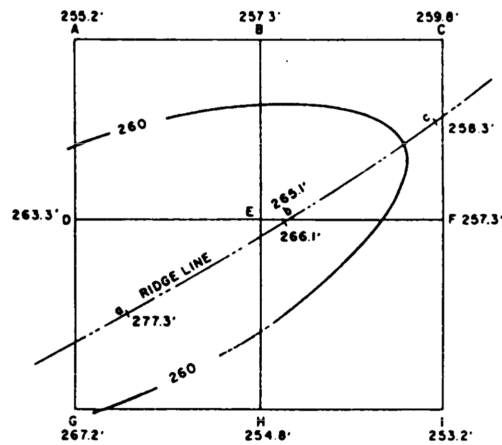


Figure 8-14.-Grid system of ground points

Assume that the slope from *A* to *D* is uniform. The difference in elevation is 8.1 feet (263.3 – 255.2) for 200.0 feet. The difference in elevation between 255.2 and 260.0 feet (elevation of the desired contour) is 4.8 feet. The distance from *A* to the point where the 260.0-foot contour crosses *AD* is the value of x in the proportional equation: 8.1:200 = *4.8:x* or x = 118.5 feet. Lay off 118.5 feet from *A* on *AD* and make a mark.

In the same manner, you locate and mark the points where the 260.0-foot contour crosses *BE,EF, EH,* and *GH.* The 260.0-foot contour crosses the ridge, obviously, between point *b* (elevation 266.1 feet) and point *c* (elevation 258.3 feet). The distance between *b* and *c* is again 200.0 feet. Therefore, you obtain the location of the point of crossing by the same procedure just described.

You now have six plotted points: one on the ridge line between *b* and *c* and the others on *AD, BE, EF, EH,* and *GH.* A line sketched by hand through these points is the 260.0-foot contour line. Note that the line is, in effect, the line that would be formed by a horizontal plane that passed through the ridge at an elevation of 260.0 feet. Note, too, that a contour line changes direction at a ridge summit.

Control Points

This explanation illustrates the fact that any contour line may be located by interpolation on a uniform slope between two points of known elevation a known distance apart. We, also, demonstrated how a ridge line is located in the same manner.

If you locate and plot all the important irregularities in an area (ridges, valleys, and any other points where

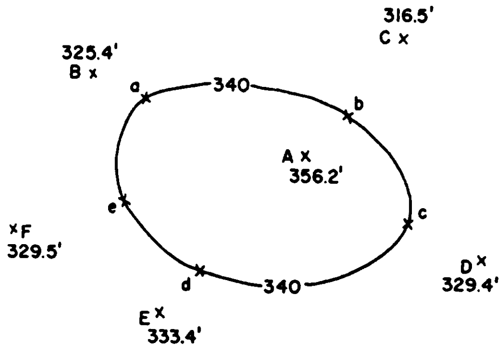


Figure 8-15.-Control-point method of locating contour.

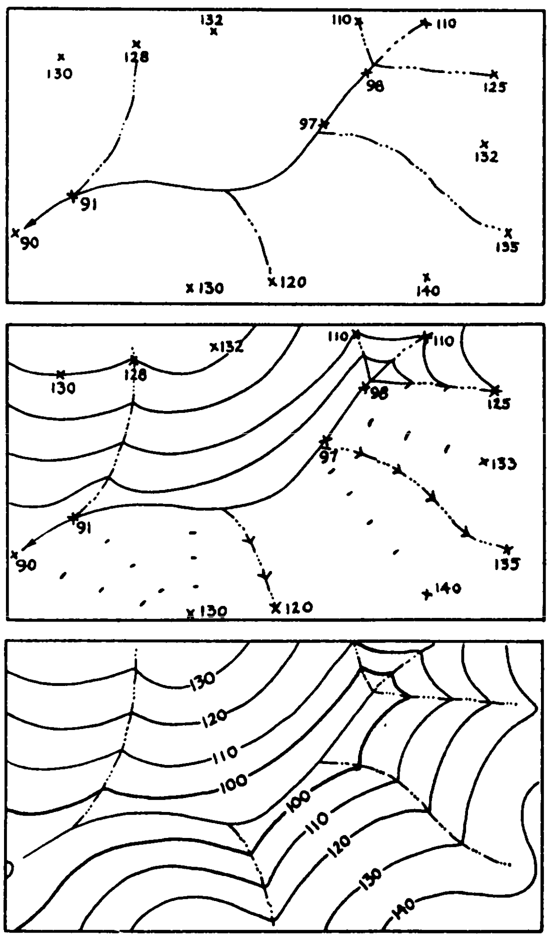


Figure 8-16.-Sketching contours by interpolation between control points of known elevations.

elevation changes radically), you can draw a contour map of the area by interpolating the desired contours between the control points.

A very elementary application of the method is shown in figure 8-15. Point *A* is the summit of a more or less conical hill. A spot elevation is taken here. Spot elevations are also taken at points B, C, *D, E,* and *F,*

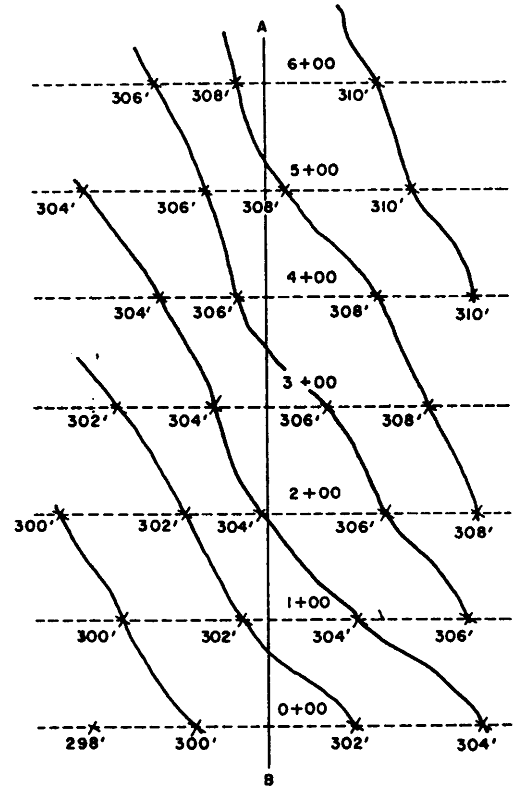


Figure 8-17.-Cross profiles.

which are points at the foot of the hill. It is desired to draw the 340.0-foot contour. Point *a* on the contour line is interpolated on the line from *A* to *B,* point *b is* interpolated on the line from *A* to *C,* point *c* is interpolated on the line from *A* to *D,* and soon.

Figure 8-16 shows a more complicated example in which contours are interpolated and sketched between controlling spot elevations taken along a stream.

Cross Refiles

In the cross-profile system, elevations are taken along selected lines that are at right angles to a traverse line. Shots are taken at regular intervals or at breaks or both in the ground slope. The method is illustrated in figure 8-17. The line *AB* is a traverse along which 100-foot stations are shown. On each of the dotted cross-section lines, contours are located. The particular contour located at a particular station depends on (1) the ground elevations and (2) the specified contour interval. In this instance, it is 2 feet. The method used to locate the contours is the one described earlier for tracing a contour system. When the even-numbered 2-foot interval contours are located on all the cross-profiles lines, the contour lines are drawn through the points of equal elevation.

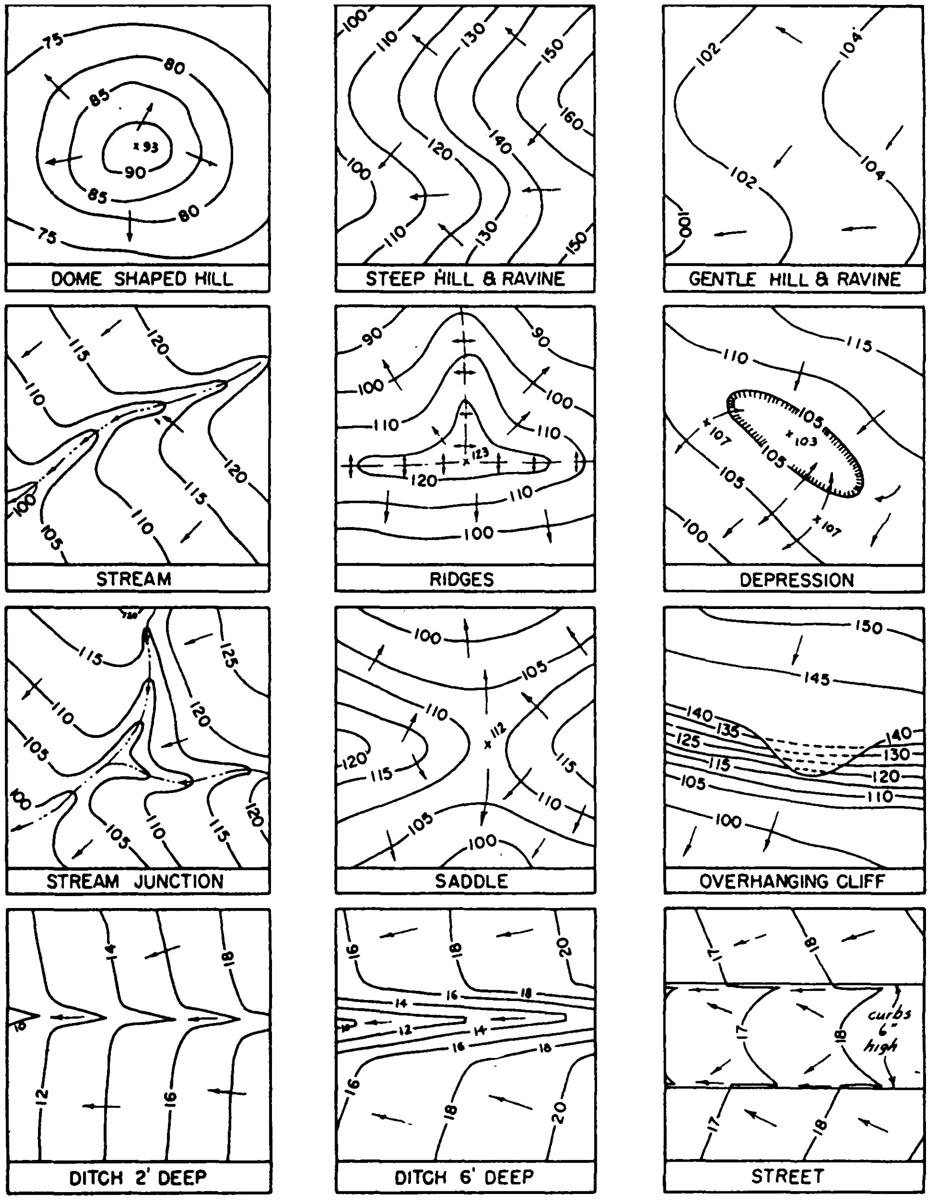


Figure 8-18.-Typical contour formations.

CHARACTERISTICS OF CONTOUR LINES

A contour line is a line of equal elevation; therefore, two different lines must indicate two different elevations. So two different contour lines cannot intersect or otherwise contact each other except at a point where a vertical or overhanging surface, such as a vertical or overhanging face of a cliff, exists on the ground Figure 8-18 shows an overhanging cliff. You can see how the segments of contour lines on this cliff are made as dotted (or hidden) lines. Aside from the exception mentioned, any point where two different contour lines intersect would be a point with two different elevations-an obvious impossibility.

In forming a mental image of the surface configuration from a study of contour lines, it is helpful for you to remember that a contour line is a level line; that is, a line that would be formed by a horizontal plane passing through the earth at the indicated elevation. If you keep this concept of levelness in mind you can usually get the “feel” of the rise and fall of the ground as you study the contour lines on the map.

A contour line must close on itself somewhere— either within or beyond the boundaries of the map. A line

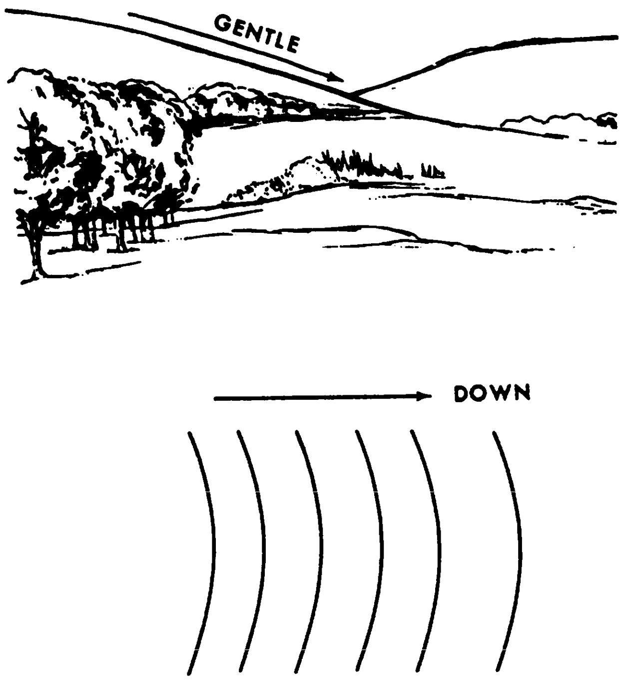


Figure 8-19.-Uniform, gentle slope.

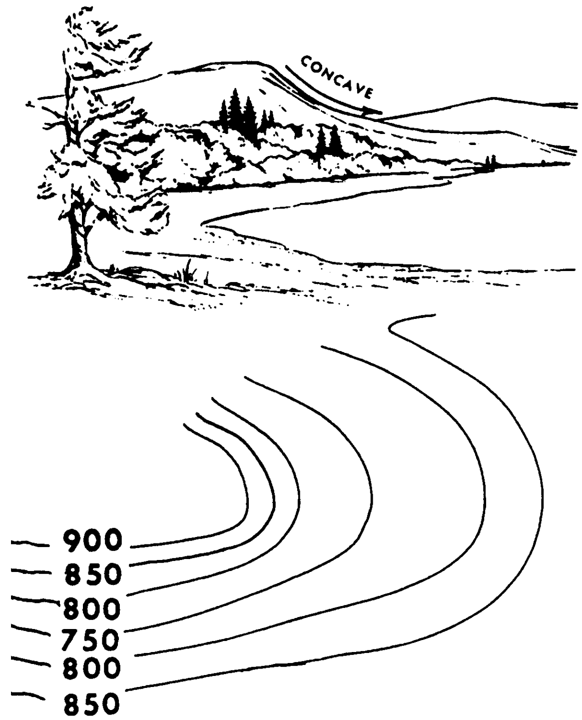


Figure 8-21.-Concave slope.

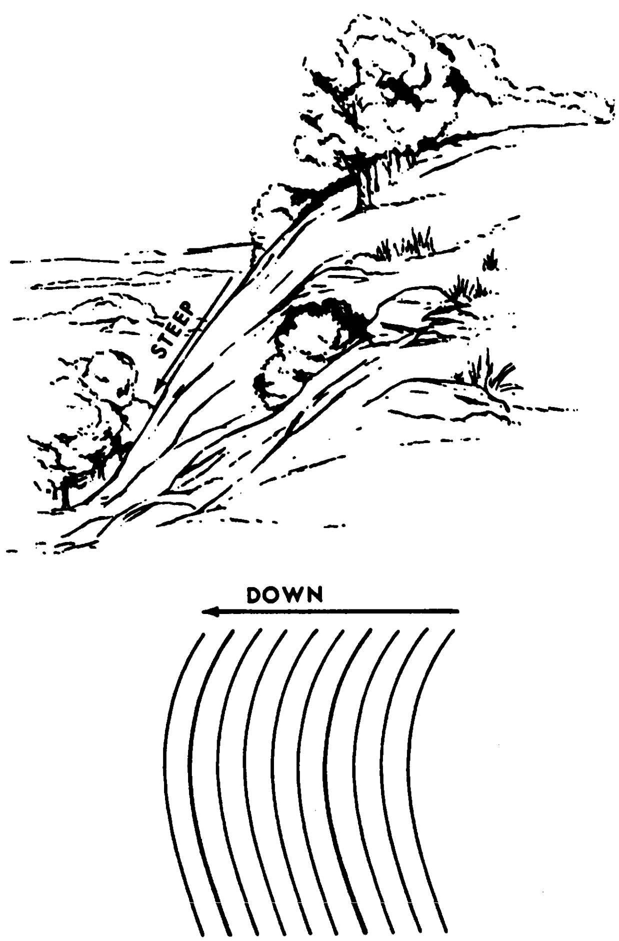


Figure 8-20.-Unifrom, steep slope.

that appears on the map completely closed may indicate either a summit or a depression. If the line indicates a depression, this fact is sometimes shown by a succession of short hachure lines, drawn perpendicular to the inner side of the line. An example of a depression is shown in figure 8-18. A contour line marked in this fashion is called a depression contour.

On a horizontal or level plane surface, the elevation of all points on the surface is the same. Therefore, since different contour lines indicate different elevations, there can be no contour lines on a level surface. On an inclined plane surface, contour lines at a given equal interval will be straight, parallel to each other, and equidistant.

A number of typical contour formations are shown in figure 8-18. For purposes of simplification, horizontal scales are not shown; however, you can see that various intervals are represented. The arrows shown indicate the direction of slope.

Generally, the spacing of the contour lines indicates the nature of the slope. Contour lines (fig. 8-19) that are evenly spaced and wide apart indicate a uniform, gentle slope. Contour lines (fig. 8-20) that are evenly spaced and close together indicate a uniform, steep slope. The closer the contour lines are to each other, the steeper the slope. Contour lines closely spaced at the top and widely spaced at the bottom indicate a concave slope (fig. 8-21).

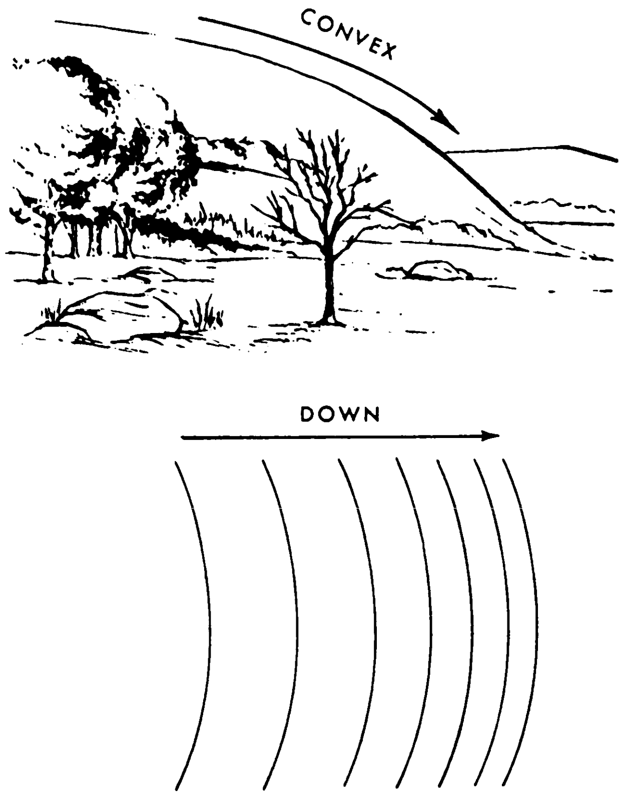


Figure 8-22.-Convex slope

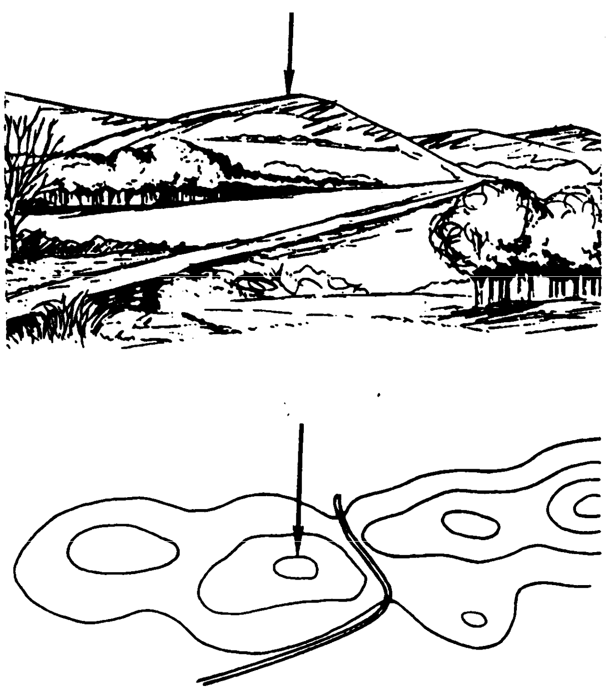


Figure 8-23.-Hill.

Contour lines widely spaced at the bottom indicate a convex slope (fig. 8-22).

A panoramic sketch is a pictorial representation of the terrain in elevation and perspective as seen from one point of observation. This type of map shows the

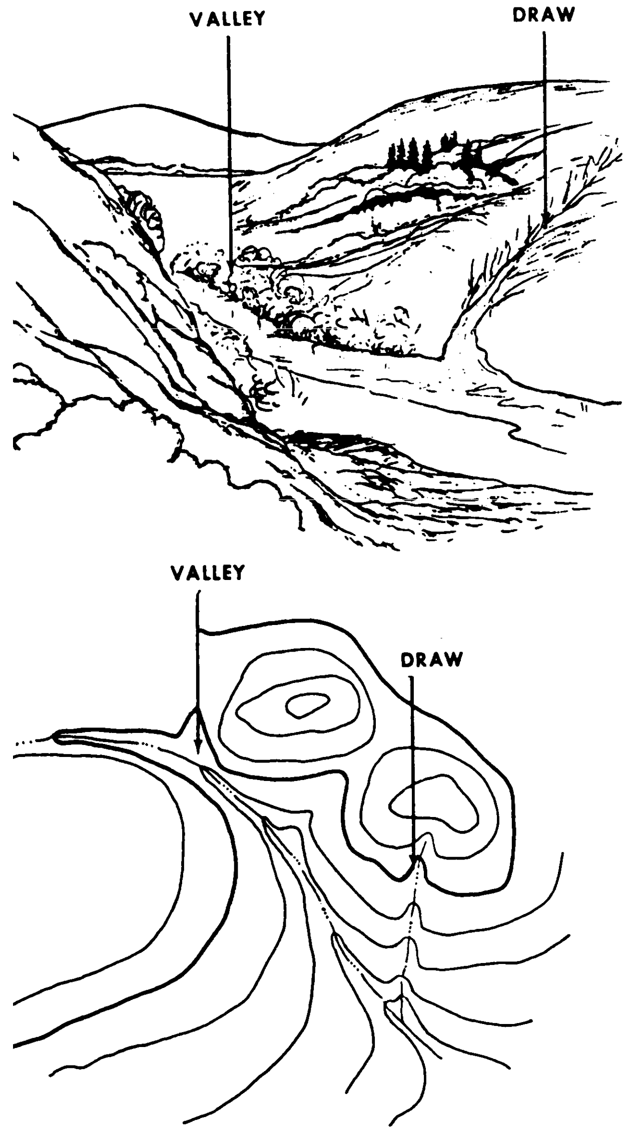


Figure 8-24.-Valley and draw.

horizon, which is always of military importance, with intervening features, such as crests, woods, structures, roads, and fences. Figures 8-23 through 8-29 show panoramic sketches and maps. Each figure shows a different relief feature and its characteristic contour pattern. Each relief feature illustrated is defined in the following paragraphs.

A hill is a point or small area of high ground (fig. 8-23). When you are on a hilltop, the ground slopes down in all directions.

A stream course that has at least a limited extent of reasonably level ground and is bordered on the sides by higher ground is a valley (fig. 8-24). The valley, generally, has maneuvering room within it. Contours indicating a valley are U-shaped and tend to parallel a major stream before crossing it. The more gradual the

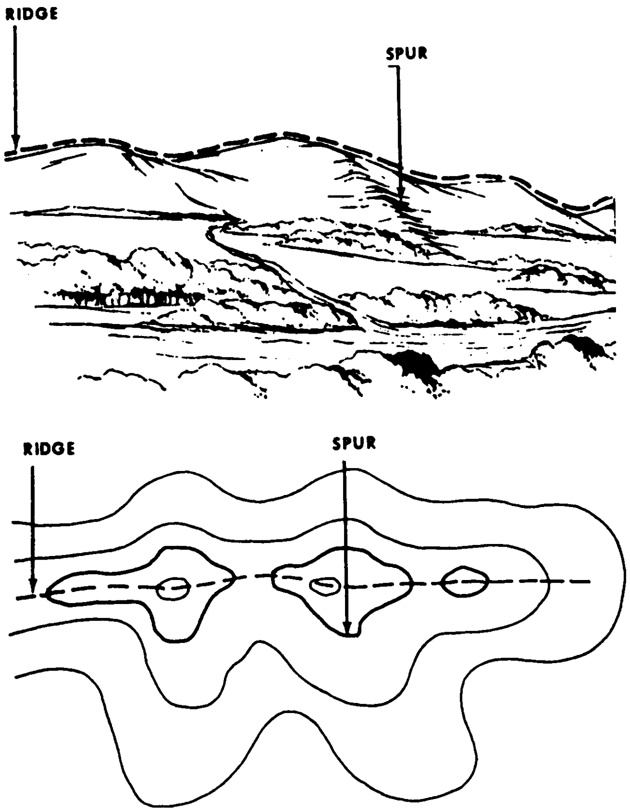


Figure 8-25.-Ridge and spur.

fall of a stream, the farther each contour parallels it. The curve of the contour crossing always points upstream.

A draw is a less-developed stream course where there is essentially no level ground and, therefore, little or no maneuvering room within its sides and towards the head of the draw. Draws occur frequently along the sides of ridges at right angles to the valley between them. Contours indicating a draw are V-shaped with the point of the V toward the head of the draw.

A ridge is a line of high ground that normally has minor variations along its crest (fig. 8-25). The ridge is not simply a line of hills; all points of the ridge crest are appreciably higher than the ground on both sides of the ridge.

A spur is usually a short continuously sloping line of higher ground normally jutting out from the side of a ridge (fig. 8-25). A spur is often formed by two roughly parallel streams that cut draws down the side of the ridge.

A saddle is a dip or low point along the crest of a ridge. A saddle is not necessarily the lower ground between the two hilltops; it maybe simply a dip or break along an otherwise level ridge crest (fig. 8-26).

A depression is a low point or sinkhole, surrounded on all sides by higher ground (fig. 8-27).

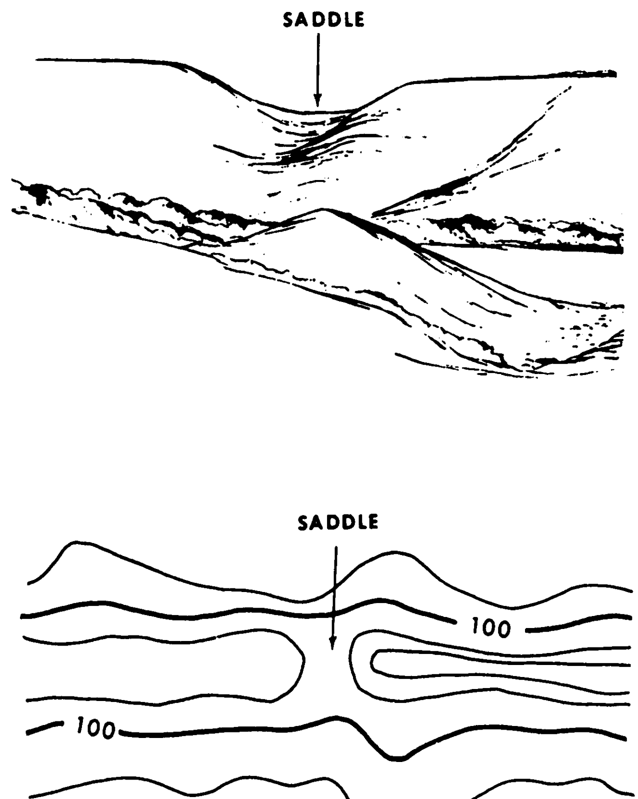


Figure 8-26.-Saddle.

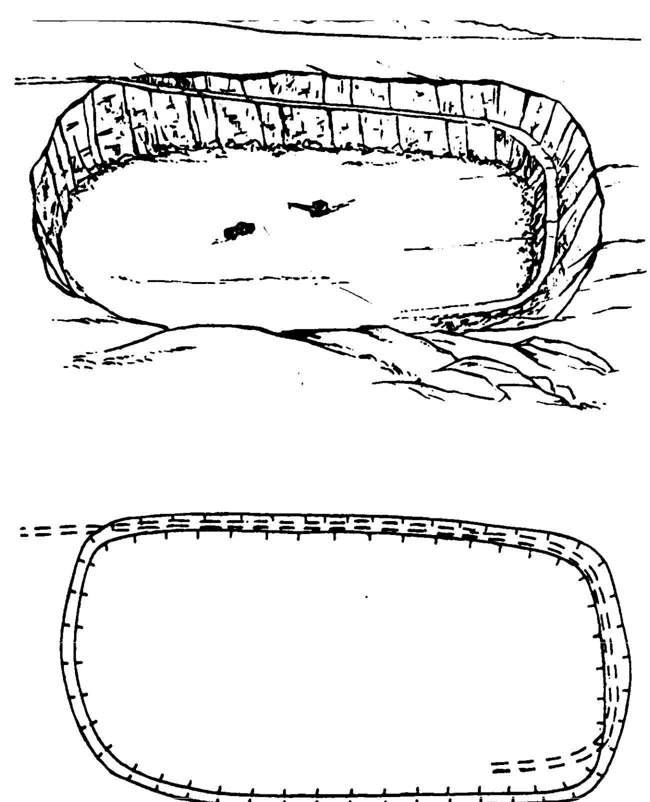


Figure 8-27.-Depression.

Table 8-1.-Recommended Contour Intervals–Topographic Map

TYPES OF TOPOGRAPHIC MAP	NATURE OF TERRAIN	RECOMMENDED CONTOUR INTERVAL IN FT
LARGE SCALE	Flat	0.5 or 1
	Rolling	1 or 2
	Hilly	2 or 5
INTERMEDIATE SCALE	Flat	1, 2, or 5
	Rolling	2 or 5
	Hilly	5 or 10
SMALL SCALE	Flat	2, 5, or 10
	Rolling	10 or 20
	Hilly	20 or 50
	Mountainous	50, 100, or 200

Cuts and fills are man-made features that result when the bed of a road or railroad is graded or leveled off by cutting through high areas and filling in low areas along the right-of-way (fig. 8-28).

A vertical or near vertical slope is a cliff. As described previously, when the slope of an inclined surface increases, the contour lines become closer together. In the case of a cliff, the contour lines can actually join, as shown in figure 8-29. Notice the tick marks shown in this figure. These tick marks always point downgrade.

MAP SCALES AND CONTOUR INTERVALS

A topographic map is called either large scale, intermediate scale, or small scale by the use of the following criteria:

Large scale: 1 inch= 100 feet or less

Intermediate scale: any scale from 1 inch= 100 feet to 1 inch= 1,000 feet

Small scale: 1 inch= 1,000 feet or more.

The designated contour interval varies with the purpose and scale of the map and the character of the terrain. Table 8-1 shows the recommended contour intervals that you may use to prepare a topographic map.

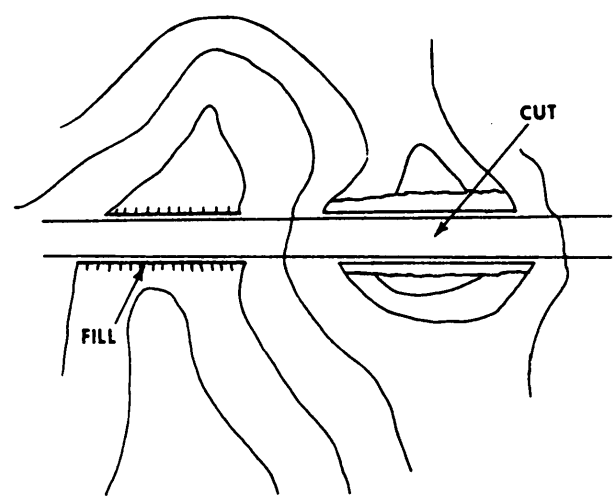


Figure 8-28.-Contour (cut and fill).

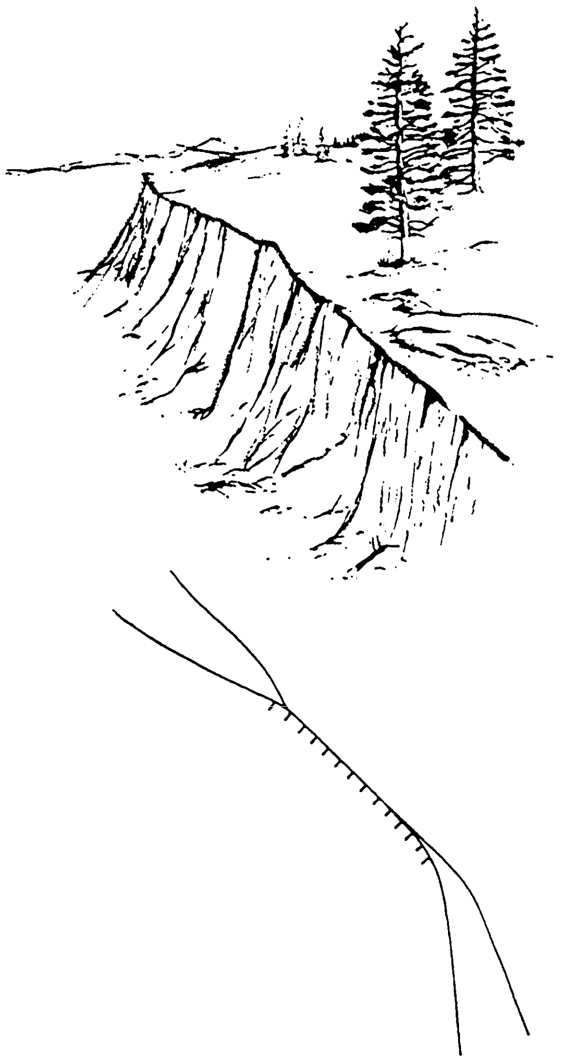


Figure 8-29.—Cliff.

CONTOUR MAP CONSTRUCTION

If EAs can perform ordinary engineering drafting chores, they will not have any difficulty in constructing a topographic map. To some degree, topographers must draw contour lines by estimation. Their knowledge of contour line characteristics and the configuration of the terrain that the contour lines represent will be a great help. Topographers must use their skill and judgment to draw the contour lines so that the lines are the best representation of the actual configuration of the ground surface.

Basically, the construction of a contour map consists of three operations. They are as follows:

1. Plot horizontal control that will serve as the framework of the map.

2. Plot details, including the map location of ground points of known ground elevation. These ground points or contour points will be used as guides for the proper location of the contour lines.

3. Construct contour lines at given contour intervals.

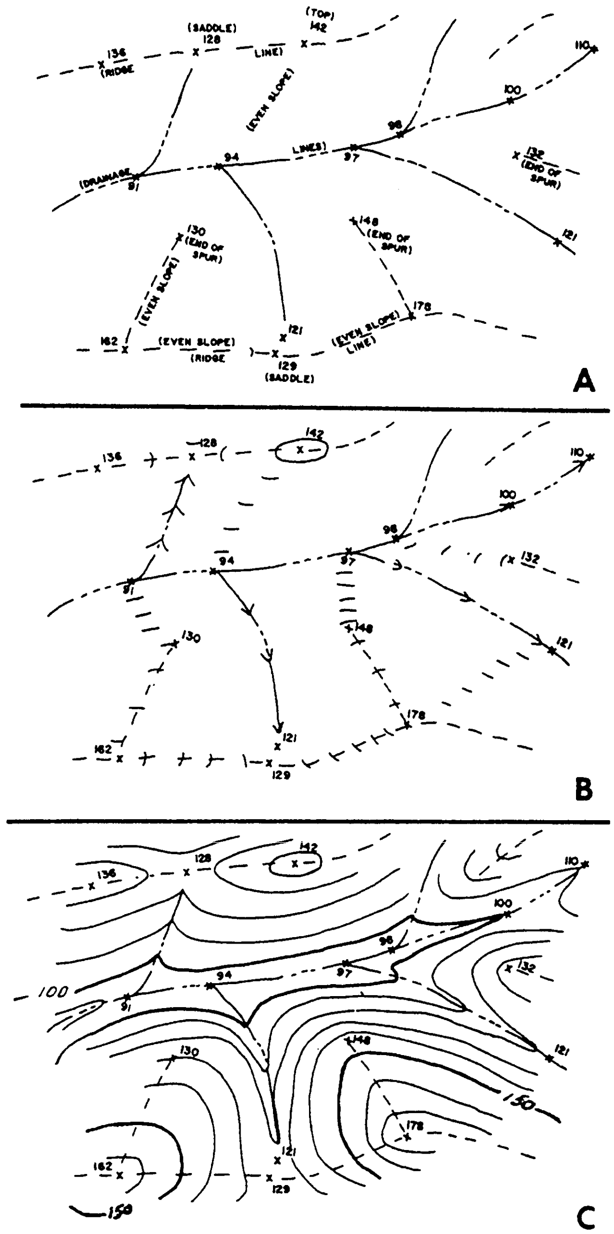


Figure 8-30.—Plotting detail and contouring.

Take special care, in the field, to locate ridge and valley lines because you usually draw these lines first on the map before plotting the actual contour points. (See fig. 8-30, view A.) Since contours ordinarily change direction sharply where they cross these lines and the slopes of ridges and valleys are fairly uniform, these lines aid you in drawing the correct contour lines. After the ridge and valley lines are plotted, space contour crossings (by interpolation) along them before

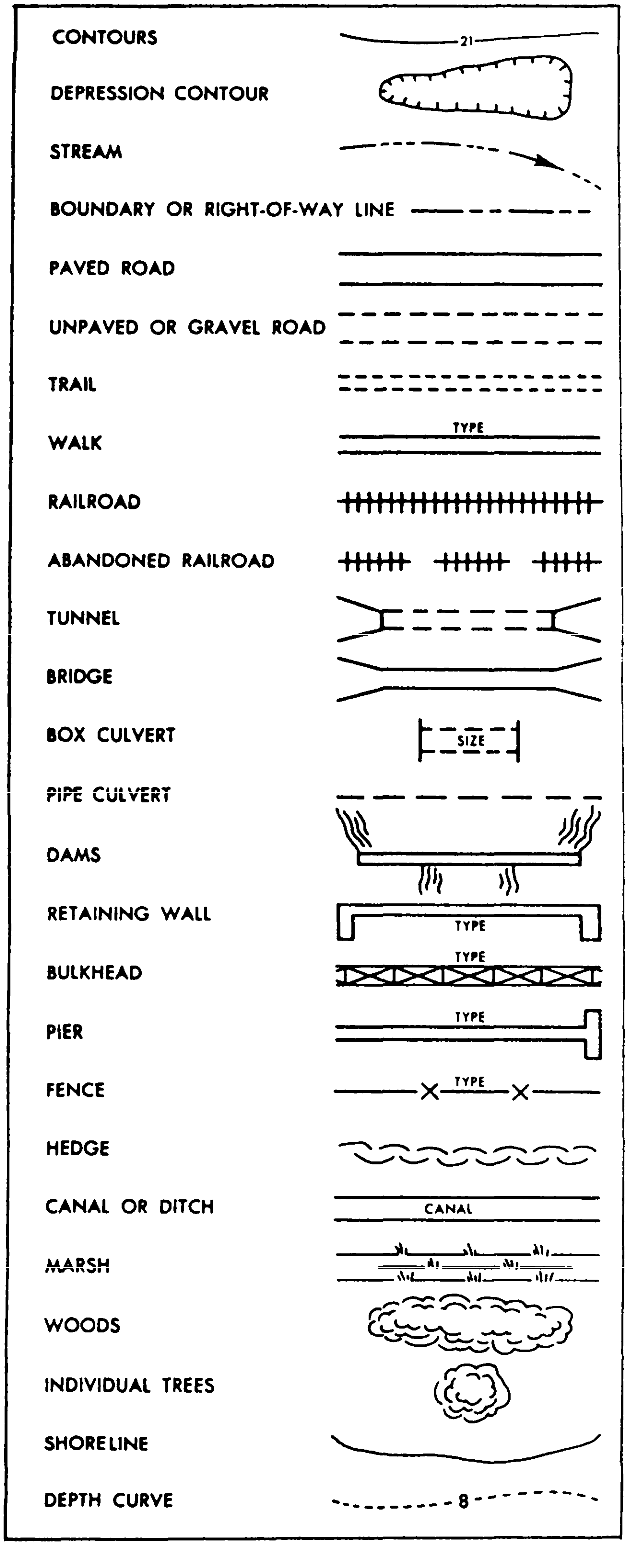


Figure 8-31.-Commonly used map symbols.

making any attempt to interpolate or to draw the complete contour lines. (See fig. 8-30, view B.)

Contour lines can be smoothly drawn freehand with uniform width and with best results if a contour pen is used. Breaks in the lines are provided to leave spaces for the elevations. The numbers that represent these elevations are written this way so that they maybe read from one or two sides of the map. Some authorities prefer that elevations also be written in a way that the highest elevation numbers are arranged from the lowest to the highest uphill. Spot elevations are shown at important points, such as road intersections.

Figure 8-30, view C, shows the completed contour map. For more refined work, the EA must trace the map, using a contour pen on tracing paper or other appropriate medium, to allow reproduction of more copies, if needed.

Often on a large-scale map, you can represent the true shape of features to scale. On small-scale maps, however, you often use symbols for buildings and other features. Center the symbol on the true position, but draw it larger than the scale of the map. Detail of this type is portrayed on the map by means of standardized topographic symbols, such as shown in figure 8-31.

When you are plotting contours, remember that stream and ridge lines have a primary influence on the direction of the contour lines. Also, remember that the slope of the terrain controls the spacing of the contour lines. Contour lines crossing a stream follow the general direction of the stream on both sides, then cross the stream in a fairly sharp V that points upstream. Also, remember that contour lines curve around the nose of ridges in the form of a U pointing downhill and cross ridge lines at approximate y right angles.

INTERPOLATING CONTOUR LINES

In the examples of interpolation previously given, a single contour line was interpolated between two points of known elevation, a known horizontal distance apart, and by mathematical computation. In actual practice, usual] y more than one line must be interpolated between a pair of points; and large numbers of lines must be interpolated between many pairs of points. Mathematical computation for the location of each line would be time-consuming and would be used only in a situation where contour lines had to be located with an unusually high degree of accuracy.

For most ordinary contour-line drawings, one of several rapid methods of interpolation is used. In each case it is assumed that the slope between the two points of known elevation is uniform.

Figure 8-32 shows the use of an engineer's scale to interpolate the contours at 2-foot intervals between *A* and B. The difference in elevation between *A* and *B* is

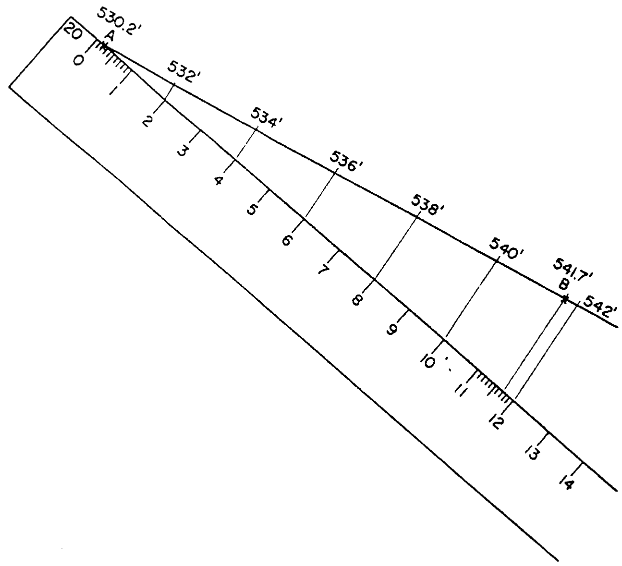


Figure 8-32.—Interpolating contour lines with a scale.

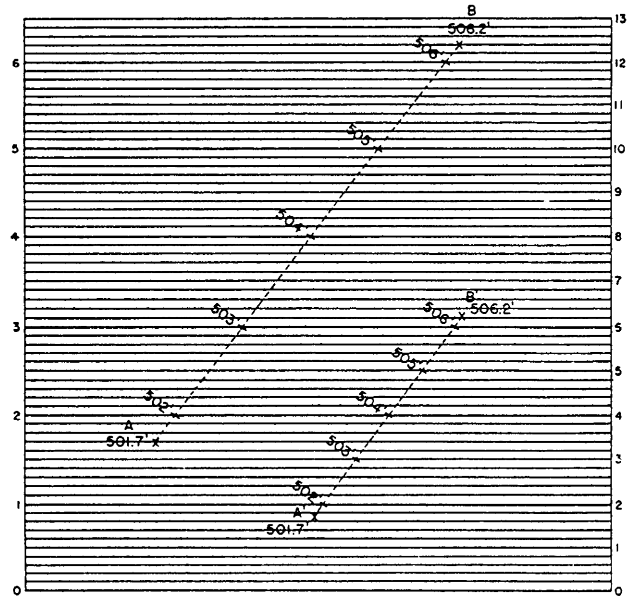


Figure 8-33.—Graphic method of interpolating contour lines.

between 11 and 12 feet. Select the scale on the engineer's scale that has 12 graduations for a distance and comes close to matching the distance between *A* and *B* on the map. In figure 8-32, this is the 20 scale. Let the 0 mark on the 20 scale represent 530.0 feet. Then the 0.2 mark on the scale will represent 530.2 feet, the elevation of *A*. Place this mark on *A,* as shown.

If the 0 mark on the scale represents 530.0 feet, then the 11.7 mark represents

530.0 + 11.7, or 541.7 feet,

the elevation of *B*. Place the scale at a convenient angle to the line from *A* to *B,* as shown, and draw a line from the 11.7 mark to *B*. You can now project the desired contour line locations from the scale to the line from *A* to *B* by drawing lines from the appropriate scale graduations (2, 4, 6, and so on) parallel to the line from the 11.7 mark to *B*.

Figure 8-33 shows a graphic method of interpolating contour lines. On a transparent sheet, draw a succession of equidistant parallel lines. Number the lines as shown in the left margin. The 10th line is number 1; the 20th, number 2, and so on. Then the interval between each pair of adjacent lines represents 0.1 feet.

Figure 8-33 shows how you can use this sheet to interpolate contour lines at a 1-foot interval between point *A* and point B. Place the sheet on the map so that the line representing 1.7 feet (elevation of *A* is 500.0 + 1.7, or 501.7 feet) is on *A,* and the line representing 6.2 feet (elevation of *B* is 500.0 + 1.7, or 506.2 feet) is on *B*. You can see how you can then locate the l-foot contours between *A* and *B*.

For a steeper slope, the contour lines would be closer together. If the contour lines were too close, you might find it advisable to give the numbers on the graphic sheet different values, as indicated by the numerals in the right-hand margin. Here the space between each pair of lines represents not 0.1 foot, but 0.2 foot. Points *A´* and B´ have the same elevations as points *A* and B, but the fact that the horizontal distance between them is much shorter shows that the slope between them is much steeper. You can see how the 1-foot contours between *A´* and B´ can be located, using the line values shown in the right margin.

A third method of rapid interpolation involves the use of a rubber band, marked with the correct, equal decimal intervals. The band is stretched to bring the correct graduations on the points.

GENERAL REQUIREMENTS FOR TOPOGRAPHIC MAPS

The scale and contour interval of a map that you are preparing will be specified according to the purpose for which the map will be used. Obviously, a map that will be used for rough design planning of a rural dirt road will be on a smaller scale and have a larger contour interval than one to be used by builders to erect a structure on a small tract in a built-up area.

The extent to which details must be shown may also be specified; if not, it is usually inferred from the purpose of the map. The following guidelines suggest the nature of typical map specifications.

A map should present legibly, clearly, and concisely a summation of all information needed for the use intended, such as planning, design, construction, or record.

Topographic maps for preliminary site planning should preferably have a scale of 1 inch = 200 feet and a contour interval of 5 feet. These maps should show all topographic features and structures with particular attention given to boundary lines, highways, railroads, power lines, graveyards, large buildings or groups of buildings, shorelines, docking facilities, large rock strata, marshlands, and wooded areas. Secondary roads, small isolated buildings, small streams, and similar minor features are generally of less importance.

Topographic maps for detailed design for construction drawings should show all physical features, both natural and artificial, including underground structures. Scales commonly used are 1 inch= 20 feet, 1 inch= 40 feet, and 1 inch = 50 feet. The customary contour interval is 1 foot or 2 feet, depending on the character and extent of the project and the nature of the terrain. Besides contour lines, show any spot elevations required to indicate surface relief.

Additional detail features that are usually required include the following:

1. Plane coordinates for grid systems, grid lines, and identification of the particular system or systems.

2. Directional orientation, usually indicated by the north arrow.

3. Survey control with ties to the grid system, if there is one. This means that the principal instrument stations from which details were located should be indicated in a suitable manner.

4. All property, boundary, or right-of-way lines with identification.

5. Roads and parking areas, including center-line location and elevation, curbs, gutters, and width and type of pavement.

6. Airport runways, taxiways, and apron pavements, including center-line locations with profile elevations and width and type of pavement.

7. Sidewalks and other walkways with widths and elevations.

8. Railroads, including center-line location, top-of-rail elevations, and any turnouts or crossovers.

9. Utilities and drainage facilities, such as gas, power, telephone, water, sanitary sewer and storm sewer lines, including locations of all valve boxes, meter boxes, handholes, manholes, and the invert elevations of sewers and appurtenances.

10. Locations, dimensions, and finished floor (usually first floor) elevations of all structures.

QUESTIONS

Q1. Describe topographic control.

Q2. Assume that you are establishing the primary vertical control for a topographic survey. The terrain is level and the desired contour interval is 1 foot. What is the maximum error closure? Can you use stadia leveling to achieve this error of closure?

Q3. You are detailing a point from a primary control station that has a known elevation of 174.3 feet. Your height instrument (h.i.) above the station is 5.6 feet. After reading a stadia interval of 2.45, you train the center hair of your telescope on the rod to match your h.i. and read a vertical angle of **+6°36'.** *If the stadia constant is 100 and the instrument constant is 1, what is the (A) horizontal distance, (B) difference in elevation and (C) elevation of the detail point? (Use the exact stadia formulas.)*

Q4. Your transit equipped with a stadia arc, is set up at point A (elevation = 245.2 feet) and you are sighting on point B. Your h.i. is 4.3 feet. The line of sight is at 5.8 on the rod and the stadia reading is 6.43. The stadia arc has index marks of H = 0 and V= 50. The stadia arc readings are V = 63 and H = 12. Your stadia constant is 100 and the instrument constant is O. What is (A) the horizontal distance to point B and (B) the elevation of B?

Q5. Define contour interval.

Q6. On a topographic map, when a contour line closes on itself, what is being portrayed?